VOLUME 06 | ISSUE 09A

digit FastTrack

YOUR HANDY GUIDE TO EVERYDAY TECHNOLOGY

TO NANO-TECHNOLOGY

- The stuff you can't see
- Nano whaa???
- Inventions and discoveries
- The devil's in the details
- Life 2.0
- The good, the bad and the ugly
- Useful info

A 9.9 Media Publication

www.thinkdigit/forum

Join the forum to express your views and resolve your differences in a more civilised way.

thinkdigit FORUM

Post your queries and get instant answers to all your technology related questions

one of the most active online technology forum not only in India but world-wide

JOIN NOW

www.thinkdigit.com

FAST TRACK to

NANOTECHNOLOGY

powered by

digit

thinkdigit.com

CONTENTS

NANOTECHNOLOGY
SEPTEMBER 2011

CREDITS
The people behind this book

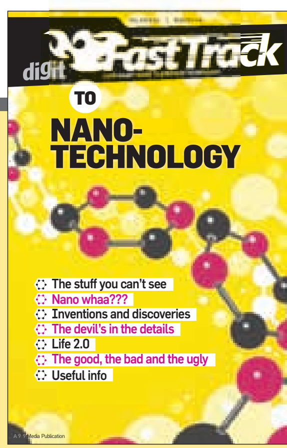
EDITORIAL

Executive Editor
Robert Sovereign-Smith

Writer
Ankur Mour

Editing
Infancia Cardozo

DESIGN
Sr. Creative Director
Jayan K Narayanan
Art Directors
Binesh Sreedharan & Anil VK
Associate Art Director
PC Anoop
Visualisers
Prasanth TR & Anil T
Senior Designers
Chander Dange, Baiju N V



COVER DESIGN: ANIL T

© 9.9 Mediaworx Pvt. Ltd.
Published by 9.9 Mediaworx
No part of this book may be reproduced, stored, or transmitted in any form or by any means without the prior written permission of the publisher.

If you want us to create a customised Fast Track for you in order to demystify technology for your community, employees or students contact editor@thinkdigit.com

September 2011
Free with Digit. If you have paid to buy this Fast Track from any source other than 9.9 Mediaworx Pvt. Ltd., please write to editor@thinkdigit.com with details

WHEN SIZE MATTERS MOST!

Over the years, you will have come across the word nanotechnology, in Digit. In fact, we see it used so often, in newspapers, on TV and on the web – as if it were a common, everyday word. However, although a lot of us will know "nano" means "small" – some will have Tata Motors to thank for that – most of us don't know anything beyond that about the massive world that exists at the miniscule atomic level. When asked, many will say, "It's the technology of the future", and will even cite articles they read, and use words such as nanobots, or buckyballs in sentences. However, we aim to imrpove that by giving you some comprehensive knowledge about what is perhaps the most exciting field of science in our era. Nanotechnology does, after all, promise to be the fountain of youth, the elixir of life, the harbinger of death and the end of mankind, all rolled into one.

We'll go small, really small – down to atomic levels. We'll take a look at nanomaterials, and how hard it is to see them, let alone manufacture them. We'll look at the breakthroughs that gave birth to this science, and take a look at where we're headed. What will a nanotech future hold in store for us? Will nanotechnology bring peace on Earth, one way or another – bring the end of terrorism, or wipe out humanity? Will we even stay human, some ask, if we've got nanobots scampering around inside us, fixing everything that breaks, transforming us into cyborgs?

We will try and answer all of these questions, and more, through the course of this book. We'll empower you with knowledge, and you can make up your own minds whether nanotechnology is really a boon or a bane. As always, we look forward to your feedback on the topic.

THE STUFF YOU CAN'T SEE

Over the past couple of decades, a new word has entered our vocabulary and that word is "nano". We read it and hear it everywhere: in the movies, the magazines, the newspapers, on television and maybe even parked on your street. Futurists say it will pave the way for unimaginable new possibilities. Pessimists are not so sure and unwilling to bet on where this dark horse will take us.

In this section, we'll try to unravel the mystery behind the word "nanotechnology" and what it constitutes. There are many different opinions about where this new field will take us, but there's no denying the fact that this science and the new technologies that come from it have the possibility of significantly impacting our world.

What is Nanotechnology?

Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometres, where unique phenomena enable novel applications. Matter such as gases, liquids and solids can exhibit unusual physical, chemical and biological properties at the nanoscale, differing in important ways from the properties of bulk material and single atoms or molecules.

Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all other science fields such as chemistry, biology, physics, materials science and engineering. Nanotechnology is not just a new field of science and engineering, but a new way of looking at and studying it.

Unit	Abbreviation	Description
Metre	m	Approximately three feet or one yard
Centimetre	cm	1/100 of a metre, about half of an inch
Millimetre	mm	1/1,000 of a metre
Micrometre	µm	1/1,000,000 of a metre, often called a micron — most integrated circuits are at this scale
Nanometre	nm	1/1,000,000,000 of a metre, the size of a single molecule

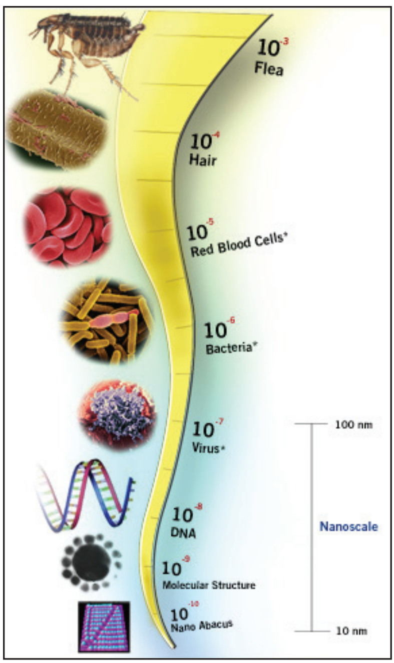
Scale of things

To actually get a feel of how small "nano" is, let's put things in perspective here. As stated previously, a nanometre is one-billionth of a metre. Everyone struggles to imagine this very small scale, but you can get an idea through comparison.

- A sheet of paper is about 100,000 nms thick
- A strand of human DNA is 2.5 nms in diametre
- There are 25,400,000 nms in 1 inch
- A human hair is approximately 80,000nms wide
- A single gold atom is about a third of a nanometre in diametre
- On a comparative scale, if the diametre of a marble was 1nm, then the diametre of the Earth would be about 1m
- One nanometre is about as long as your fingernail grows in one second

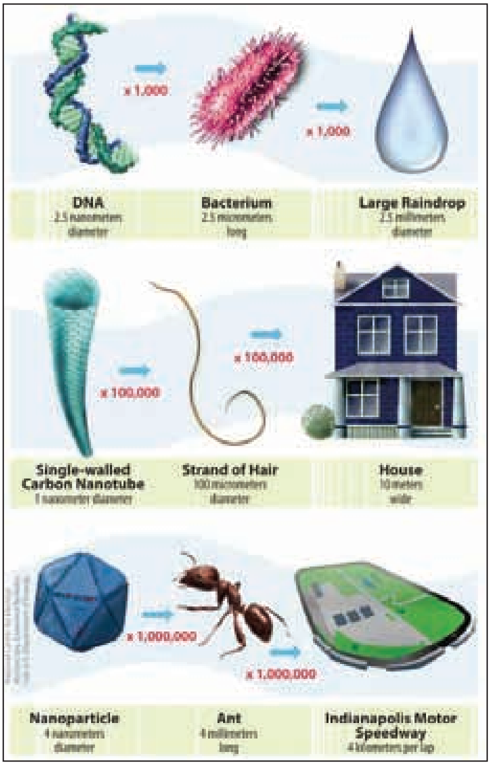
For better understanding, we'll look at nanotechnology in three parts:

- Seeing at the nanoscale
- Working at the nanoscale
- Manufacturing at the nanoscale



Scale of the things we're talking about

Seeing



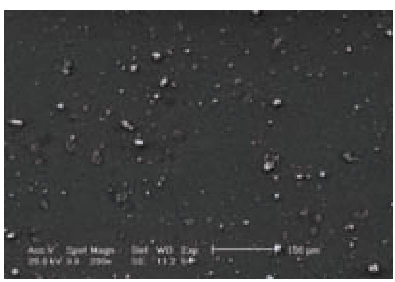
Putting things in perspective

As you've probably guessed by now, it's no easy task for scientists to see what's going on in the extremely small world of nanotechnology. You need are high-powered microscopes that use unique methods to allow visibility of surface features on the atomic scale, thus introducing you to the world of modern nanotechnology.

Beginning as early as the 1930s, scientists were using instruments such as the scanning electron microscope, the transmission electron microscope and the field ion microscope for this purpose. The most recent and notable developments in microscopy are the scanning tunneling microscope and the atomic force microscope.

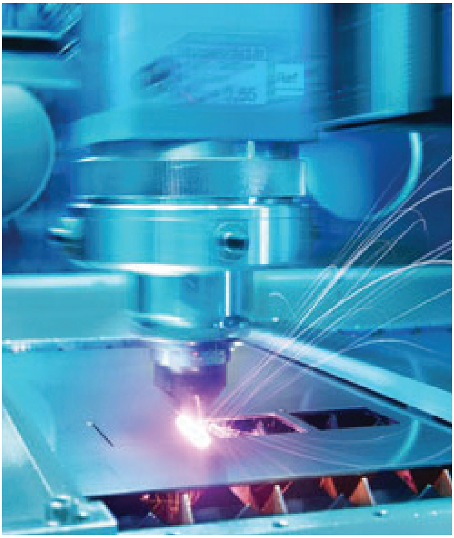
Working

Nanotechnology requires the ability to understand and precisely manipulate and control those materials in a useful way. It demands an understanding of the various types and dimensions of nanoscale materials. Different types of nanomaterials are named for their individual shapes and dimensions - particles, tubes, wires, films, flakes or


Seeing at the nanoscale

shells that have one or more nanometre-sized dimensions. For example, carbon nanotubes measure a diametre in the nano-scale, but can be several hundred nanometres long or even longer. Nanofilms or nanoplates have a thickness in the nanoscale, but their other two dimensions can be much larger.

The key is to be able to both, see and manipulate nanomaterials in order to take advantage of their special properties.



Working at the nanoscale

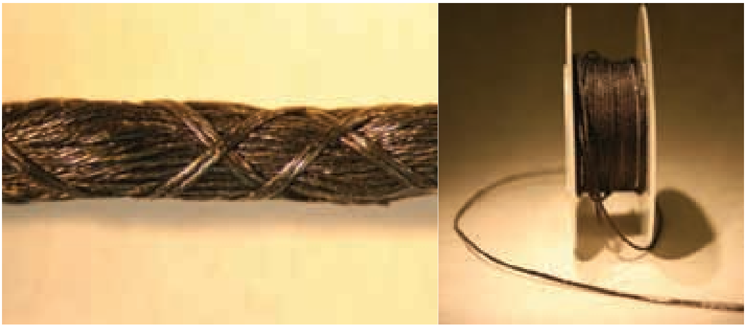
Manufacturing

Manufacturing at the nanoscale is known as nanomanufacturing. Nanomanufacturing involves scaled-up, reliable and cost-effective manufacturing of nanoscale materials, structures, devices and systems.

There are two basic approaches to nanomanufacturing: top-down and bottom-up.

- **Using the top-down method,** researchers selectively modify the starting material much like an artist creates a sculpture from a slab of marble. This method is more traditional, in that, material is altered (e.g. removed, added to, etc.) by mechanical or chemical means. Photolithography and electron beam lithography are examples of top-down approaches that are used extensively in the semiconductor industry to fabricate integrated electronic circuitry.
- **Using the bottom-up method,** researchers seek to build larger and more complex systems molecule by molecule. With this method, molecules are designed and created with the ability to spontaneously self-assemble when a chemical or physical trigger is applied. Nature routinely uses this method. Although bottom-up processes are less developed and understood, they hold great promise for the future.

Structures and properties of materials can be improved through these nanomanufacturing processes and can be made stronger, lighter, more durable,



Manufacturing at the nanoscale

water-repellent, anti-reflective, self-cleaning, ultraviolet or infrared-resistant, anti-fog, anti-microbial, scratch-resistant or electrically conductive, among other traits.

What changes at the nanoscale?

Computer simulation of electron motions within a nanowire

While microscale objects (objects with dimensions one-millionth of a metre in size) are widely used, they haven't caused the same excitement as nanoscale materials. The reason is that microscale objects have essentially the same properties as bulk material. However, at the nanoscale the fundamental properties of materials depend on their size, shape and composition in a way that they don't at any other scale. So, the nanoscale is a different kind of small. Size-dependent properties are the reason that nanoscale objects have the potential to significantly impact both, science and industry.

Quantum effects

When particles are created with dimensions of about 1-100 nms, the so-called quantum effects rule the behaviour and properties of particles. Properties such as melting point, fluorescence, electrical conductivity, magnetic permeability and chemical reactivity change as a function of the size of the particle.

Nanoscale gold illustrates the unique properties that occur at the nanoscale. Nanoscale gold particles are not the yellow color with which we're familiar; they appear red or purple. At the nanoscale, the motion of the gold's electrons is confined. Because this movement is restricted, gold nanoparticles react differently to light compared to larger-scale gold particles. Their size and optical properties make them ideal candidates for practical use in tumour treatment. These nanoscale gold particles selectively accumulate in tumors, where they can enable both, precise imaging and targeted laser destruction of the tumor by means that avoid harming healthy cells.

A fascinating and powerful result of the quantum effects of the nanoscale is the concept of "tunability" of properties. That is, by changing the size of the particle, a scientist can literally fine-tune a material's property of interest (e.g., changing fluorescence colour; in turn, the fluorescence color of a particle can be used to identify the particle, and various materials can be "labelled" with fluorescent markers for various purposes). Another potent quantum effect of the nanoscale is known as "tunneling". The scanning tunneling microscope and flash memory is based on this technology

Biology

Over millennia, nature has perfected the art of biology at the nanoscale. A strand of DNA, one of the building blocks of human life, is only about two nanometres in diametre.

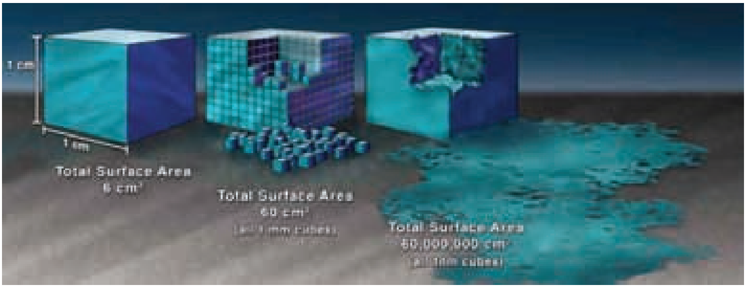
Drawing on the natural nanoscale of biology, many medical researchers are working on designing tools, treatments and therapies that are more precise and personalised than conventional ones – and that can be applied earlier in the course of a disease thus leading to fewer adverse side-effects. Some scientists are looking at ways to use nanoscale biological principles of molecular self-assembly, self-organisation and quantum mechanics to create novel computing platforms.

Surface areas

Nanoscale materials have far larger surface areas than similar masses of larger-scale materials. We'll illustrate this with a simple thought experiment:

A solid cube of a material 1 cm on a side has 6 cms2 of surface area, about equal to one side of half a stick of gum.

But if that volume of 1 cm^3 were filled with cubes 1 mm on a side, that would be 1,000 mm-sized cubes (10 x 10 x 10), each one of which has a surface area of 6 mms2 , for a total surface area of 60 cms2 – about the same as two thirds



The effect of the increased surface area

of one side of a 3-inch x 5-inch note card.

When the 1 cm^3 is filled with micrometre-sized cubes –a trillion (1012) of them, each with a surface area of 6 µm2 –the total surface area amounts to 6 m2, or about the area of the main bathroom in an average house.

And when that single cubic centimetre of volume is filled with 1nm-sized cubes –1021 of them, each with an area of 6 nms2 – their total surface area comes to 6,000 m2. In other words, a single cubic centimetre of cubic nanoparticles has a total surface area larger than a football field!

Large surface area translates to:

1. Better reactivity
2. Creation of better catalysts
3. Use of nanostructured membranes and materials for water treatment and desalination
4. Support to "functionalisation" of nanoscale material surfaces.

As of 2003, catalyst technologies accounted for over $1 trillion of revenue in the US economy and about a third of the material GDP. This lets you gauge the potential that Nanotechnology can help us unlock. Nanotechnology is not simply working at ever smaller dimensions; rather, working at the nanoscale enables scientists to utilise the unique physical, chemical, mechanical and optical properties of materials that naturally o ccur at that scale.

Do we need Nanotechnology?

We need nanotechnology. There are no ifs and buts about it. It will raise our standard of living, make our lives more secure, improve healthcare delivery and optimise our use of limited resources. We can already see many of the possibilities. New products that solve new problems in new ways are more difficult to foresee, yet their impact is likely to be even greater.

Healthcare

With nanotechnology, what's beneath our skin is going to be more accessible to us than ever before:

- Hospitals will benefit greatly from nanotechnology with faster, cheaper diagnostic equipment. The lab-on-a-chip will be able to analyse a patient's ailments in an instant, providing point-of-care testing and drug application. New contrast agents will float through the bloodstream, lighting up problems such as tumours with incredible accuracy. Diagnostic tests will become more portable, providing time-sensitive diagnostics out in the field in ambulances. New-born children will have their DNA quickly mapped, pointing out future potential problems, allowing us to curtail diseases before they happen.

The future is Nanomedicine

- Nanotechnology will aid in the delivery of just the right amount of medicine to the exact spots of the body that need it most. Nanoshells, approximately 100nm in diametre, will float through the body, attaching only to cancer cells. When excited by a laser beam, the nanoshells will give off heat – in effect, cooking the tumour and destroying it. Nanotechnology will create biocompatible joint replacements and artery stents that will last the life of the patient instead of it having to be replaced every few years.

Resources

We undoubtedly are facing a future with curtailed and vanishing resources – be it water or energy. Nanotechology can enable us to replenish these resources:It can provide new methods to effectively utilise our current energy resources while also presenting new alternatives. Cars will have lighter and stronger engine blocks and frames and will use new additives making fuel more efficient. House lighting will use quantum dots – nanocrystals 5nm across – in order to transform electricity into light instead of wasting away into heat.

- Nanotechnology will cut costs both, of the solar cells and the equipment

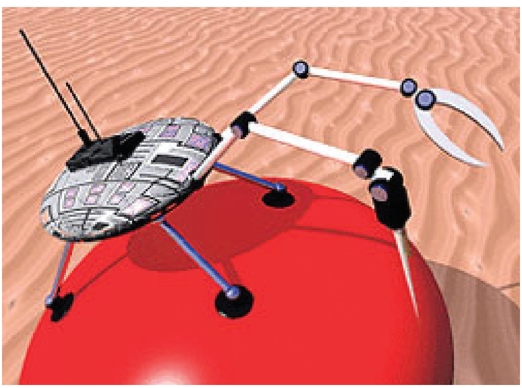

The future energy source

needed to deploy them, making solar power economical. In this application, we need not make new or technically superior solar cells: making inexpensively what we already know how to make expensively would move solar power into the mainstream.

- Nanotechnology will provide efficient water purification techniques, allowing third-world countries access to clean water. When we satisfy our energy requirements, desalinisation of water from our oceans will not only provide enough water to drink but also to water our crops.

Military

- With superior lightweight materials, nanotechnology could revolutionise tanks, airframes, spacecraft, skyscrapers, bridges and body armour, providing unprecedented protection. Kevlar, the backbone fibre of bulletproof vests, will be replaced with materials that not only provide better protection but also store energy and monitor the health status of our soldiers.
- Smart weapons will get smaller in the form of smart bullets. A single bullet could pack more computer power than the largest supercomputer in existence today, allowing them to perform real-time image analysis of their surroundings and communicate with weapons


A nanobot in action

tracking systems to acquire and navigate to targets with greater precision and control.

- Varying the size of nanometals, such as nanoaluminum, will give us control over the explosion of munition and thereby minimise collateral damage. Incorporating nanometals into bombs and propellants increases the speed of released energy with fewer raw materials consumed.
- Chemical sensors based on nanotechnology will be incredibly sensitive – capable, in fact, of pinpointing a single molecule out of billions. These sensors will be cheap and disposable, forewarning us of airport-security breaches or anthrax-laced letters. These sensors will eventually take to the air on military unmanned aerial vehicles (UAVs), not only sensing chemicals but also providing incredible photo resolutions. These photos, condensed and on an energy-efficient, high resolution, wristwatch-sized display, will find their way to the soldier, providing incredible real-time situational awareness at the place needed most: the front lines.

Computing

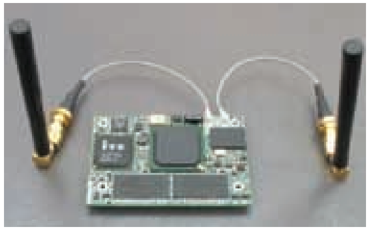
- Today, computer chips are made using lithography – literally, "stone writing". If the computer hardware revolution is to continue at its current pace, in a decade or so we'll have to move beyond lithography to some new post-lithographic manufacturing technology. Ultimately, each logic element will be made from just a few atoms. Designs for computer gates with less than 1,000 atoms have already been proposed – but each atom in such a small device has to be in exactly the right place. To economically build and interconnect trillions upon trillions of such small and precise devices in a complex three-dimensional pattern we'll need a manufacturing technology well beyond today's lithography: we'll need nanotechnology.

Levitation is the way to go

- We'll be able to build mass storage devices that can store more than a hundred billion billion bytes in a volume the size of a sugar cube; RAM

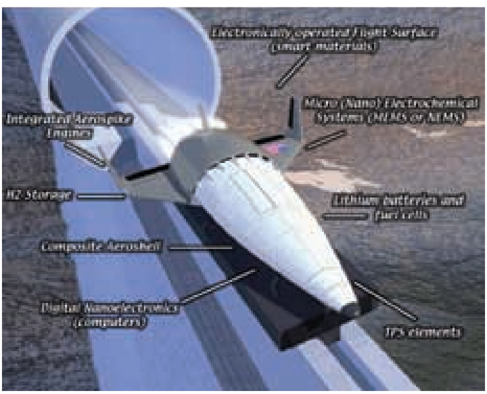
that can store a mere billion billion bytes in such a volume; and massively parallel computers of the same size that can deliver a billion billion instructions per second.

- More powerful and smaller computers will encrypt our data and provide round-the-clock security. Quantum cryptography – cryptography that utilises the unique properties of quantum mechanics – will provide unbreakable security for businesses, government and military. These same quantum mechanics will be used to construct quantum computers capable of breaking current encryption techniques.


Small is the way forward

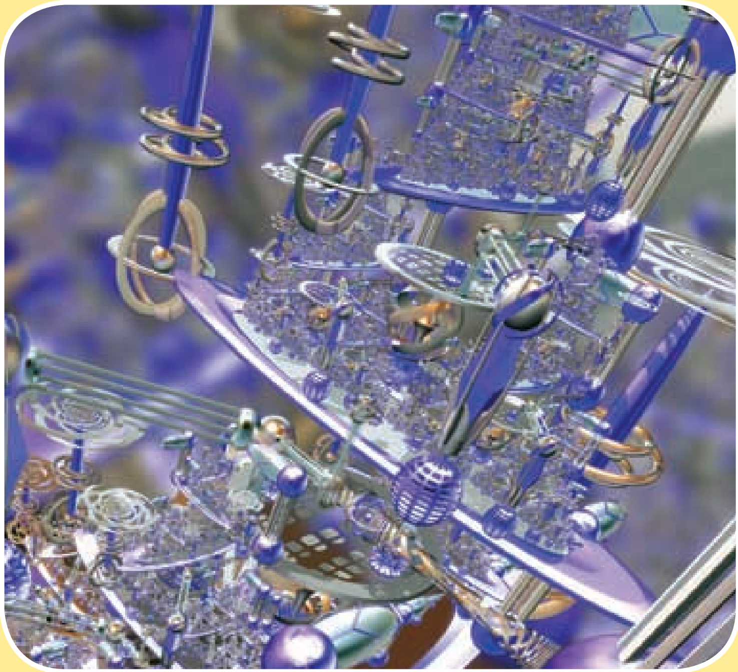
Transportation

- Today, most airplanes are made from metal despite the fact that diamond has a strength-to-weight ratio over 50 times that of aerospace aluminum. Nanotechnology will let us inexpensively make shatterproof diamond (with a structure that might resemble diamond fibres) in the exact shapes we want. This would let us make a Boeing 777 whose unloaded weight is 50 times lighter but just as strong.



Future transportation to zip you there faster

- Today, travel in space is very expensive and reserved for an elite few. Nanotechnology will dramatically reduce the costs and increase the capabilities of spaceships and space flight. It will also provide extremely powerful computers with which to guide both, those ships and a wide range of other activities in space. Mars, Jupiter, and someday, Andromeda, all within reach!



NANO WHAA???

Nanomaterials are defined as those materials which have structured components with at least one dimension less than 100nm. They are the building blocks of practical nanotechnology and can be physically and chemically manipulated for specific application.

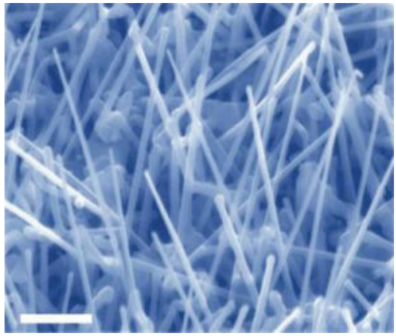
Nanomaterials are defined as those materials which have structured components with at least one dimension less than 100nm. Much of nanoscience and many nanotechnologies are concerned with producing new or enhanced "nanomaterials". These nanomaterials can be constructed by 'top-down' as well as by 'bottom-up' techniques. Current applications of nanoscale materials include very thin coatings used in electronics and active surfaces. Based on the number of nano-dimensions, nanomaterials can be:

- One-dimensional in the nanoscale and extended in the other two dimensions. Examples are layers, such as a thin films or surface coatings.
- Two-dimensional in the nanoscale and extended in one dimension. Examples include nanowires and nanotubes.
- Three-dimensional, e.g. Particles like precipitates, colloids and quantum dots.


Tip of Gold imaged by SEM

As we discussed earlier, two principal factors cause the prop-

erties of nanomaterials to differ significantly from other materials: increased relative surface area and quantum effects. These factors can change or enhance properties such as reactivity, strength and electrical characteristics, particularly as the structure or particle size approaches the smaller end of the nanoscale.



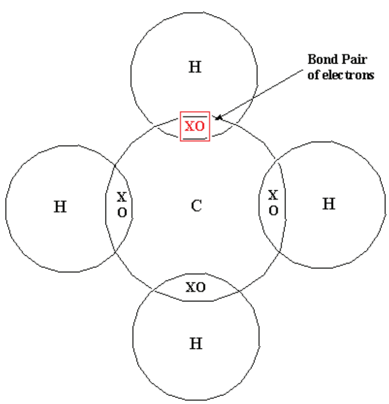
Nanowires – an example of 2d Nanomaterial

To understand how nanomaterials will be used, you need a clear look not only at how they're formed but also at their various configurations. In this section, we look at nano building blocks, and how they're currently being used to enhance all kinds of materials and products. While some of this work is still in the research phase, other work is already being employed in the consumer products and applications industry.

Carbon

Carbon can be regarded as the ubiquitous building block of nanomaterials, and it isn't difficult to see why. Carbon atoms can be found in millions of molecules. These molecules have a wide range of properties, and there are three main reasons behind it:

1. Carbon atoms can bond together with many types of atoms using a process called covalent bonding. In covalent bonding, the atoms that bond (and are held together in a molecule) share two electrons. If the ability of each atom to attract all those negatively charged electrons (called electronegativity) is reasonably close (that is, if the difference in electronegativity is no more than 2), then they can form covalent bonds. Because the electronegativity of carbon atoms is 2.5 (roughly in the mid-range), they can form



Covalent Bonds of Carbon

strong, stable, covalent bonds with many other types of atoms with higher or lower values. When carbon atoms bond with different types of atoms, they form molecules with properties that vary according to the atoms they've bonded with.

2. Each carbon atom can form these covalent bonds with four other atoms at a time. That's more bonds than most other atoms can form. Each nitrogen atom (for example) can form only three covalent bonds, each oxygen atom can form only two covalent bonds, and so on. This four-bond capability allows carbon atoms to bond to other carbon atoms to make chains of atoms – and to bond with other kinds of atoms at various points along such chains.

3. There's no other element in the periodic table that bonds as strongly to itself and in as many ways as the carbon atom. Carbon atoms can bond together in short chains, in which case they may have the properties of a gas. They may bond together as long chains, which might give you a solid material, like plastic. Or, they can bond together in 2- or 3-dimensional lattices, which can make for some very hard materials, such as diamonds.

Hence it's only natural that carbon atoms will find uses in nanomaterials.

Classification: One dimension

Thin films, layers and surfaces

One-dimensional nanomaterials, such as thin films and engineered surfaces, have been developed and used for decades in fields such as electronic device manufacturing, chemistry and engineering. If you went to a silicon integrated-circuit industry, for example, you'll witness many devices relying on thin films for their operation, and control of film thicknesses approaching the atomic level is routine. Monolayers (layers that are one atom or molecule deep) are also routinely made and used in chemistry. The formation and properties of these layers are reasonably well understood from the atomic level upwards, even in quite complex layers (such as lubricants). Advances are being made in the control of the composition and smoothness of surfaces and the growth of films.

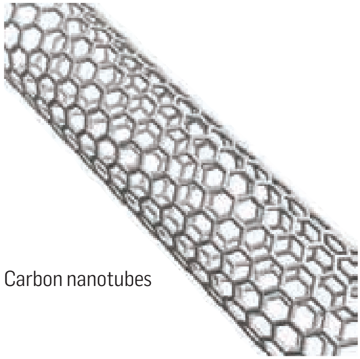
Engineered surfaces with tailored properties such as large surface area or specific reactivity are used routinely in a range of applications such as in fuel cells and catalysts. The large surface area provided by nanoparticles, together with their ability to self-assemble on a support surface, could be of use in all of these applications.

Although they represent incremental developments, surfaces with enhanced properties should find applications throughout the chemicals and energy sectors. The benefits could surpass the obvious economic and resource savings

achieved by higher activity and greater selectivity in reactors and separation processes, to enabling small-scale distributed processing (making chemicals as close as possible to the point of use). There's already a move in the chemical industry towards this. Another use could be the small-scale, on-site production of high value chemicals such as pharmaceuticals.

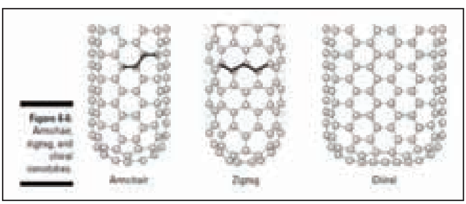
Two dimension

Carbon Nanotubes


Carbon nanotubes

As far back as 1959, Roger Bacon had produced images of carbon nanotubes. In the 1980s, Howard Tennant applied for a patent for a method to produce them. In 1990, Richard Smalley postulated the concept that if buckyballs get big enough, they become carbon cylinders. But it wasn't until 1991 that Sumio Iijima, a researcher at NEC's Fundamental Research Lab, not only took photos of nanotubes, but also put two and two together to explain what nanotubes actually are — and put a name to them.

CNTs are nothing but extended tubes of rolled graphene sheets. Nanotubes come in a couple of varieties. They can either be single-walled carbon nanotubes (SWNT) or multiwalled carbon nanotubes (MWNT). As you might expect, an SWNT is just a single cylinder, whereas an MWNT consists of multiple concentric nanotube cylinders,


Different arrangements of CNT

One property of nanotubes is that they're really, really strong. Tensile strength is a measure of the amount of force an object can withstand without tearing apart. The tensile strength of carbon nanotubes is approximately 100 times greater than that of steel of the same dia.

Nanotubes are strong but are also elastic. This means it takes a lot of force to bend a nanotube, but the little guy will spring right back to its original shape when you release it, just like a rubber band does. Young's modulus for carbon

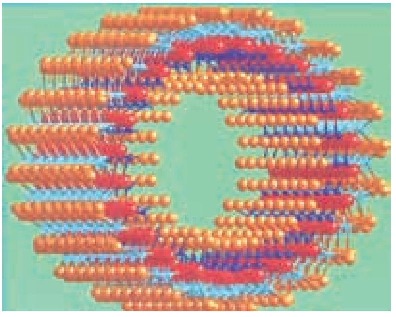
nanotubes, a measurement of how much force it takes to bend a material, is about 5 times higher than for steel. In addition to being strong and elastic, carbon nanotubes are also lightweight, with a density about one quarter that of steel.

As if that weren't enough, carbon nanotubes also conduct heat and cold really well (they have a high thermal conductivity); some researchers predict a thermal conductivity more than 10 times that of silver — and if you've ever picked up a fork from a hot stove, you know silver and other metals are pretty darn good conductors of heat.

CNTs are an example of the true power of nanotechnology. They open an incredible range of applications in materials science, electronics, chemical processing, energy management, and many other fields. It is already being used as Field Emitters, Energy Storage, Catalyst support, Biomedical applications among others.

Inorganic Nanotubes

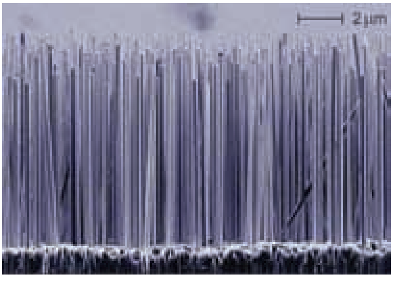
Inorganic nanotubes are based on layered compounds such as molybdenum disulphide and were discovered shortly after CNTs. They have excellent tribological (lubricating) properties, resistance to shockwave impact, catalytic reactivity, and high capacity for hydrogen and lithium storage, which suggest a range of promising applications.



Inorganic Nanotubes

Nanowires

Nanowires are ultrafine wires or linear arrays of dots, formed by self-assembly. They can be made from a wide range of materials. Semiconductor nanowires made of silicon, gallium nitride and indium phosphide has demonstrated remarkable optical, electronic and magnetic characteristics. Nanowires have potential

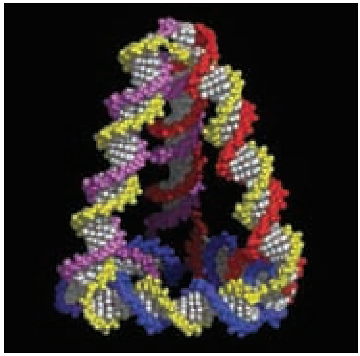


Silicon nanowires

applications in high-density data storage; either as magnetic read heads or as patterned storage media, and electronic and opto-electronic nanodevices, for metallic interconnects of quantum devices and nanodevices.

Biopolymers

Biopolymers (such as DNA molecules) via virtue of their variability and site recognition, offer a wide range of opportunities for the self-organization of wire nanostructures into much more complex patterns. The DNA backbones may then, for example, be coated in metal. They also offer opportunities to link nano- and bio-technology in, for example, biocompatible sensors and small, simple motors.

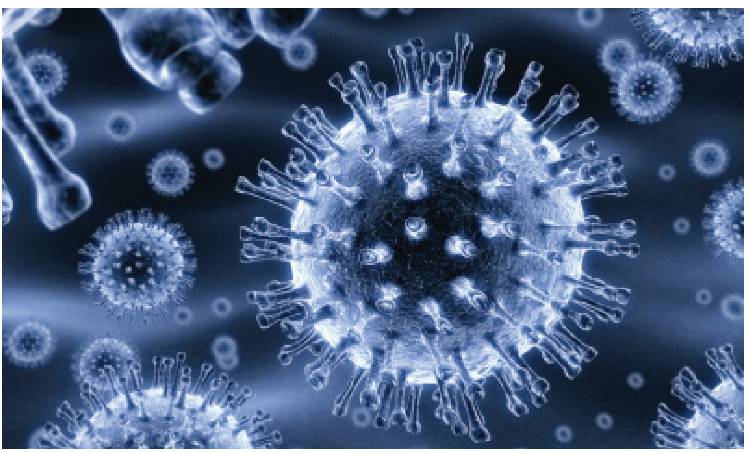


A structure of biopolymers

Three dimensions

Nanoparticles

Nanoparticles are often defined as particles of less than 100nm in dia. But some scientist classify nanoparticles to be particles less than 100nm in dia that "exhibit new or enhanced size-dependent properties" compared with larger particles of the same material.

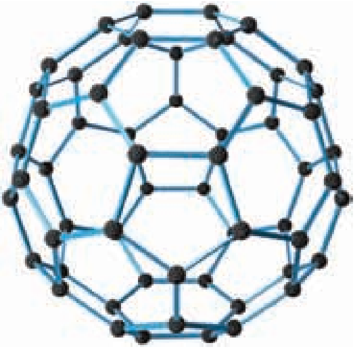


The key to the future?

Nanoparticles are of interest because of the new properties (such as chemical reactivity and optical behaviour) that they exhibit compared with larger particles of the same materials. For example, titanium dioxide and zinc oxide become transparent at the nanoscale and are able to absorb and reflect UV light, and have found application in sunscreens. The bending of bulk copper (wire, ribbon, etc.) occurs with movement of copper atoms/clusters at about the 50 nm scale. Copper nanoparticles smaller than 50 nm are considered super hard materials that do not exhibit the same malleability and ductility as bulk copper.

In the short-term, nanoparticles can be used in new cosmetics, textiles and paints and in the longer term, it has its applications in methods of targeted drug delivery where they could be to used deliver drugs to a specific site in the body.

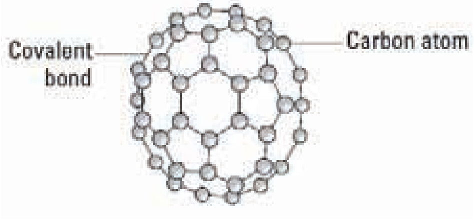
Fullerenes (Buckyballs)



Buckyballs

Buckyballs were discovered through an interesting collaboration of researchers from two universities. Richard Smalley at Rice University was studying semiconductor materials. He had a device that shined a laser at a solid sample, vaporized part of it, and analyzed the clusters of atoms that formed in the vapor. Meanwhile, at the University of Sussex, Harry Kroto as well as Bob Curl were attempting to reproduce a material found in deep space that generated specific molecular spectra from carbon atoms. Bob Curl, also from

Rice University, was doing similar work. When Kroto dropped by Rice, and saw the work that Smalley was doing, he became interested in using that equipment to reproduce his carbon molecules.. In August of 1985, Smalley, Kroto, Curl, and some graduate students performed a series of experiments producing carbon molecules and clusters. They found that under certain conditions, most of the molecules generated contained 60 carbon atoms.

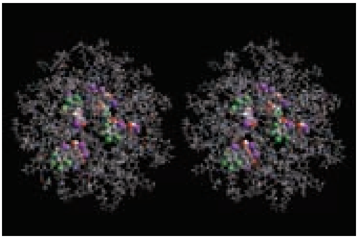


Carbon Bonding in Buckyballs

After much discussion and modeling, researchers determined that 60 carbon atoms form a single stable molecule only if they're arranged in 20 hexagons and 12 pentagons that are linked to form a sphere — as it happens, it's the same arrangement of hexagons and pentagons proposed by American architect and engineer Buckminster Fuller for his famed geodesic dome. In his honor these molecules got dubbed as buckminsterfullerenes.

Several applications are envisaged for fullerenes, such as miniature 'ball bearings' to lubricate surfaces, drug delivery vehicles and in electronic circuits. In accordance with this vision, several companies and universities have started developing methods for mass-manufacture of fullerenes. MIT, working with a company called Nano-C, Inc., developed a method called combustion synthesis, which produces big enough quantities of buckyballs — at a low enough cost — for use in commercial applications.

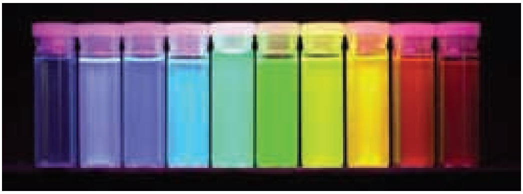
Dendrimers


An intricate structure of Dendrimer

Dendrimers, formed through a nanoscale hierarchical self-assembly process, are spherical polymeric molecules, There are of many types - the smallest being several nanometres in size. Dendrimers are used in conventional applications such as coatings and inks, but they also have a range of interesting properties which could lead to useful applications. Environmental clean-up could be assisted by dendrimers as they can trap metal ions, which could then be filtered out of water with ultra-filtration techniques.

Quantum Dots

Quantum dots were theorized in the 1970s and initially created in the early 1980s. As we learned earlier, if these quantum dots (semiconductor particles) are made small enough, quantum effects come into play, which limit the energies at which electrons and holes can exist in the particles. As

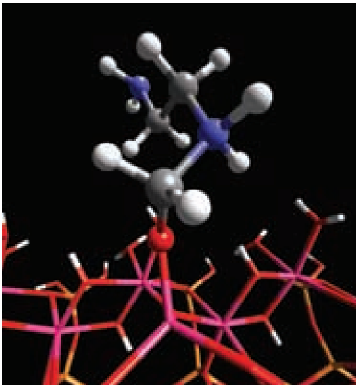

Different colours exhibited by quantum dots

energy is related to wavelength (or colour), this means that the optical properties of the particle can be finely tuned depending on its size. Thus, particles can be made to emit or absorb specific wavelengths (colours) of light, merely by controlling their size.

Quantum dots have found applications in composites, solar cells, fluorescent biological labels etc. Recent advances in chemistry have resulted in the preparation of monolayer-protected, high-quality, monodispersed, crystalline quantum dots as small as 2nm in dia, which can be conveniently treated and processed as a typical chemical reagent.

Nanocomposites

A nanocomposite is a matrix to which nanoparticles have been added to improve a particular property of the material. It is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanos (nm), or structures having nano-scale repeat distances between the different phases that make up the material.


An artist's rendition of nanocomposite

In the broadest sense nanocomposite include porous media, colloids, gels and copolymers. Understandably the mechanical, electrical, thermal, optical, electrochemical, catalytic properties of the nanocomposite will differ markedly from that of the component materials. Size limits for these effects have been proposed as

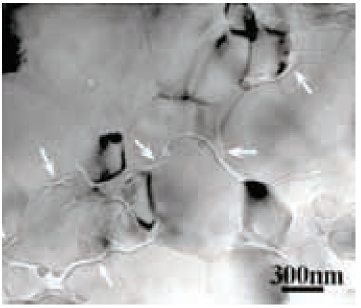
- Less than 5 nm for catalytic activity,
- Less than 20 nm for making a hard magnetic material soft
- Less than 50 nm for refractive index changes, and
- Less than 100 nm for achieving superparamagnetism, mechanical strengthening or restricting matrix dislocation movement.

In mechanical terms, nanocomposites differ from conventional composite materials due to the exceptionally high surface to volume ratio of the reinforcing phase and/or its exceptionally high aspect ratio. The area of the interface between the matrix and reinforcement phase(s) is typically an order of magnitude greater than for conventional composite materials. The matrix material properties are significantly affected in the vicinity of the reinforcement. The large amount of

reinforcement surface area means that a relatively small amount of nanoscale reinforcement can have an observable effect on the macroscale properties of the composite. For example, adding carbon nanotubes improves the electrical and thermal conductivity.

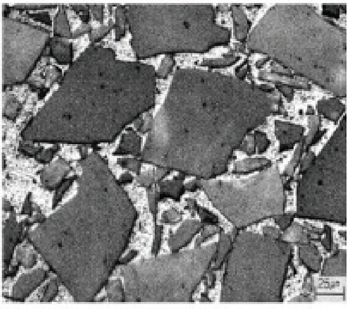
They are generally divided into:

1. **Ceramic-matrix nanocomposites:** This group of composites is mainly made of ceramic (a chemical compound from the group of oxides, nitrides, borides, silicides etc) and a metal as the second component, which are finely dispersed in each other in order to elicit the particular nanoscopic properties.



Ceramic-matrix nanocomposites

2. **Metal-matrix nanocomposites:** This energy nanocomposite when combined with metal oxides and nano-scale aluminum powder, forms superthermite materials.
3. **Polymer nanocomposites:** This group of composites is mainly made from a polymer or copolymer having dispersed nanoparticles. An example of a nanopolymer is silicon nanospheres which show quite different characteristics; their size is 40 – 100 nm and they are much harder than silicon, their hardness being between that of sapphire and diamond.

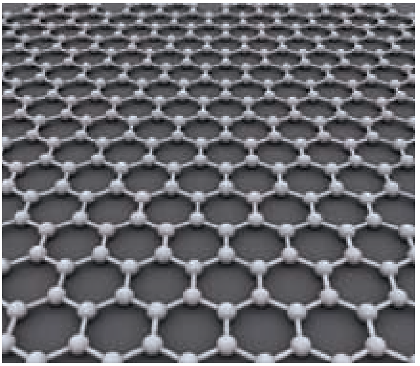

Metal matrix nanocomposite

Applications of Nanocomposites under Development:

- Producing batteries with greater power output.
- Speeding up the healing process for broken bones.
- Producing structural components with a high strength-to-weight ratio
- Using graphene to make composites with even higher strength-to-weight ratios.
- Making lightweight sensors
- Making flexible batteries.
- Making tumors easier to see and remove.

Graphenes

Graphene is an allotrope of carbon, whose structure is most easily visualized as an atomic-scale chicken wire made of carbon atoms and their bonds. The term graphene was coined as a combination of graphite and the suffix -ene by Hanns-Peter Boehm, who described single-layer carbon foils in 1962. The carbon-carbon bond length in graphene is about 0.142 nanos. Graphene sheets stack to form graphite with an interplanar spacing of 0.335 nm, which means that a stack of three million sheets would be only one milli thick. Graphene is the basic structural element of some carbon allotropes including graphite, charcoal, carbon nanotubes and fullerenes. Graphene won scientists, Andre Geim and Konstantin Novoselov the Nobel Prize in Physics for 2010.



The structure of Graphene

It is speculated that graphene ribbons can be produced by cutting open carbon nanotubes. In one such method multi-walled carbon nanotubes are cut open in solution by action of potassium permanganate and sulfuric acid. In another method, graphene nanoribbons are produced by plasma etching of nanotubes partly embedded in a polymer film.

Potential applications of Graphene:

- Making components with higher strength to weight ratios
- Making Transistors that operate at higher frequency
- Lowering cost of display screens in mobile devices
- Storing hydrogen for fuel cell powered cars
- Developing Sensors to diagnose diseases.

INVENTIONS AND DISCOVERIES

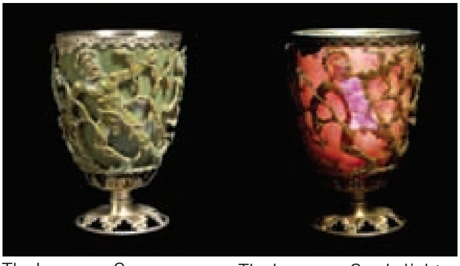
In this section, we'll try and trace the history of Nanotechnology. We'll be taking a look at how Nanotechnology has managed to impact human lives everywhere and the huge leaps since then that has enabled us with the understanding to go about unlocking doors to potential new discoveries.

We will start from pre-modern examples of nanotechnology of medieval glass workers to the present day nano-sized silicon tips, capable of chiseling out a relief map of the world from a substrate of organic molecular glass.

Pre-modern Examples of Nanotechnology (pre-1800s)

Roman Period (30BC – 640AD)

Anyone who thinks that nanotechnology is a modern phenomenon will find contradicted by archaeological evidences. The word may not have existed, but it was certainly being put to use by the Romans. The Lycurgus Cup which now resides in the British Museum in London is an example of dichroic glass. Transmission Electron Microscopy reveals that this glass contains nanoparticles of colloidal gold and silver, which turns this opaque green cup into a glowing translucent red when light shines through the inside. Although it is highly likely that the unique properties of this ancient Roman piece were created by accident, it is still the earliest surviving example of the use of Nanotechnology materials.

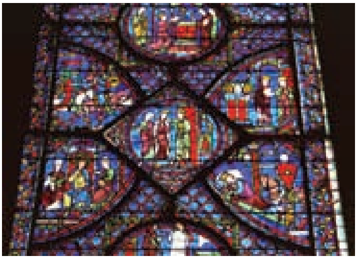


The Lycurgus Cup Without light. The Lycurgus Cup In light.

Medieval Period (500AD – 1450AD)

Just like their earlier Roman counterparts, Medieval Glass artists were the accidental users of nanotech-

nology. Vibrant stained glass windows in European cathedrals owed their rich colours to nanoparticles of gold chloride and other metal oxides and chlorides: Ruby Red is due to gold nanoparticles while Deep Yellow is due to silver nanoparticles. It is the size of these particles that produced the colour variations and as our modern scientists will agree, the dramatic change in material properties at the nano-scale is a vital component of nanotechnology. Research has also shown that nanoparticles of gold, when activated by sunlight, can destroy air–borne pollutants such as methanol and other volatile organic chemicals


Stained Glass Windows in a Church

The 9th century AD Abbasid potters in what is today Iraq, used a decorative technique called lusterware, which involves using a lead-based glaze to create a golden shine on a pot without gold in it. Although the potters considered it to be true alchemy, we know that they owed it to the silver or copper or other metallic nanoparticles.


Abbasid Pottery

Renaissance Period (1450AD – 1600AD)

Artisans colouring pottery in Derula, Umbria were also practicing a similar form of nanotechnology, like their Abbasian counterparts. Derula ceramicists were producing iridescent and metallic glazes by using nanoparticles of copper and silver metal. Instead of scattering light, these particles caused light to bounce off their surface at different wavelengths, giving them the high-in-demand metallic effects.


Damascus Saber Blades

The "Damascus" saber blades contained carbon nanotubes and cementite nanowires—an ultrahigh-carbon steel formulation that gave them strength, resilience, the ability to hold a keen edge, and a visible moiré pattern in the steel that give the blades their name.

Modern Era Developments and Discoveries

Photography (1827)

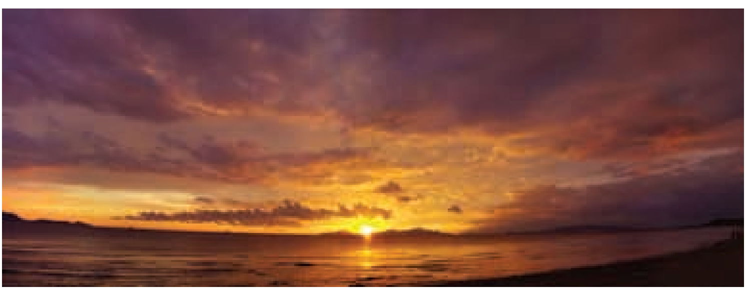
One of the earliest examples of Nanotechnology from the Nineteenth century is photography, which depends on the production of silver nanoparticles sensitive to light. Photographic film is a thin layer of gelatin containing silver halides and a base of transparent cellulose acetate. The light decomposes the silver halides, producing nanoparticles of silver, which are the pixels of the photographic image. Although the British scientists Thomas Wedgewood and Sir Humphry Davy were the pioneers in this field, the first successful photograph was produced in 1827, by Joseph Niepce using material that hardened on exposure to light. His partner Louis Daguerre discovered a way of developing photographic plates in 1839 and also to make permanent images by immersing it in salt.

Michael Faraday (1857)

Considered by many to be one of the greatest experimentalists who ever lived, the English chemist and physicist, Michael Faraday discovered and prepared the first metallic colloids (fine particles that suspend in a solution) in 1856. Faraday's gold colloids had special electronic and optical properties, and are now known as one of the many interesting metallic nanoparticles. His "ruby" gold colloid, demonstrated that nanostructured gold under certain lighting conditions produces different-coloured solutions.

MIE Theory(1908)

The MIE theory of light scattering, as proposed by the German physicist, Gustav Mie explains how different sized particles create the colours we see in the sky. His theory shows that light scatters from particles more efficiently at short wavelengths than at long wavelengths. This is the reason we perceive the sky as blue during the day and as a mixture of red and yellow during sunset. He unwittingly



Light Scattering Phenomenon

played a hand in the development of nanotechnology with this theory as well as with the method he devised of calculating the size of particles by determining the light they scatter.

First Electron Microscope (1931)

Working with Max Knott, the German Scientist Ernst Ruska developed the world's first Electron Microscope that would enable us to recognise object that were smaller than the wavelength of light. It transcended the wavelength of visible light and exceeded the detail and clarity of the traditional light microscope. This was an important step in the development of techniques and instrumentation that would eventually enable research in the nanoscale.

World's First Electron Microscope

The Transitor (1947)

Until the mid-194O's,the electronic world depended on vacuum tubes for almost everything - Converting AC to DC, Amplifying an electronic signal, Switching telephone calls, Building the high-speed computer, ENIAC. However their bulky yet fragile nature as well as their tendency to overheat, was a hindrance to the electronics world. In 1947 William Shockley, Walter Brattain and John Bardeen working at Bell Labs created the world's first point-contact transistor. They went on to receive the Nobel Prize in physics and their invention of the transistor and the integrated circuit marked the beginning of microelectronics, a field that relies on tools for miniaturisation. The semiconductor industry is one of the largest technology drivers in the field of nanotechnology.

World's First Transistor

Mondisperse Colloidal Materials (1950)

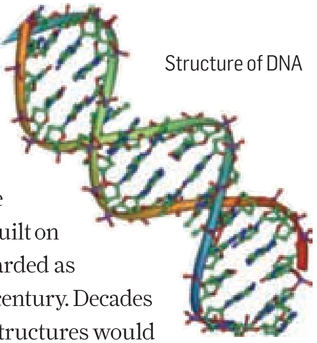
Victor La Mer and Robert Dinegar developed the theory and a process for growing monodisperse colloidal materials. Controlled ability to fabricate colloids enables myriad industrial uses such as specialised papers, paints, and thin films, even dialysis treatments.

Field Ion Electron Microscope (1951)

Erwin Mueller, a professor at Penn State University's department of physics, made an important contribution to Nanotechnology when he invented the field-ion electron microscope in 1951. For the first time in history, individual atoms and their arrangement on a surface could be seen. The device was a landmark advance in scientific instrumentation that allowed a magnification of more than 2 million times

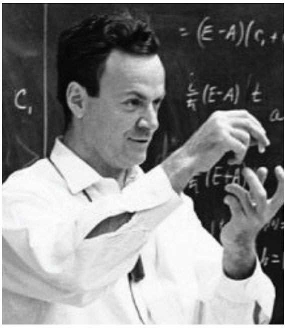
Field Ion Electron Microscope

Discovery of DNA (1953)



Structure of DNA

In 1953, Dr. James Watson and Professor Francis Crick published an article in Nature describing the double helix structure of DNA- deoxyribonucleic acid – which carried genetic information. They showed that when cells divide, the two strands that make up the DNA helix separate and a new "other half" is built on each strand, a copy of the one before. It is regarded as one of the landmark achievements of the 20th century. Decades later, DNA's ability to self-assemble into tiny structures would inspire researchers to use the same principles to develop nano-scale structures with specific dimensions and chemical properties.



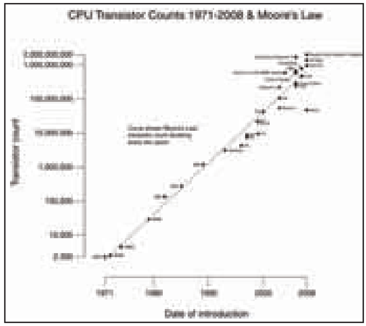
Richard Feynman at Caltech

Richard Feynman (1959)

On December 29, 1959 Richard Feynman of the California Institute of Technology, gave what is considered to be the first lecture on technology and engineering at the atomic scale, "There's Plenty of Room at the Bottom" at an American Physical Society meeting at Caltech. In his speech he stated, "What I want to talk about is the problem of manipulating and controlling things on a small scale. In the year 2000, when they look back at this

age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction." Without ever using the word "nanotechnology" he predicted the possibilities and potentials of nano-sized materials.

Moore's Law (1965)



Graph of Moore's Law

Intel co-founder Gordon Moore described in Electronics magazine several trends he foresaw in the field of electronics. One trend now known as "Moore's Law," described the density of transistors on an integrated chip (IC) doubling every 12 months (later amended to every 2 years). Moore's prediction turned out to be prophetic. In fact, the complexity of a chip continued to double yearly, long after 1975. The rate of doubling has only recently slowed to about every 18 months. That the basic trend Moore envisioned has continued for 50 years is to a large extent due to the semiconductor industry's increasing reliance on nanotechnology as ICs and transistors have approached atomic dimensions.

Coining the Term (1974)

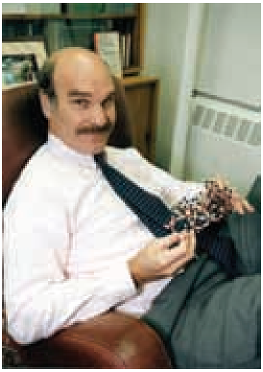

Norio Taniguchi

Tokyo Science University Professor Norio Taniguchi coined the term nanotechnology to describe precision machining of materials to within atomic-scale dimensional tolerances.

He used the word to refer to "production technology to get the extra high accuracy and ultra-fine dimensions, i.e. the preciseness and fineness on the order of 1 nano."

Molecular Electronics (1974)

In 1974, Northwestern University Charles and Emma Morrison Professor of Chemistry, Mark A. Ratner and A. Aviram of IBM, proposed that individual molecules might exhibit the behavior of basic electronic devices, thus allowing computers to be built from the bottom up by turning individual molecules into circuit components. This hypothetical application of nanotechnology,



Father of molecular-scale electronics

formulated long before the means existed to test it, was so radical that it wasn't pursued or even understood for another 15 years. For this ground-breaking work, Ratner is credited as the "father of molecular-scale electronics" and his contributions were recognised in 2001 with the Feynman Prize in Nanotechnology.

SERS (1977)

In 1977 Richard P. Van Duyne from the Northwestern University discovered Surface Enhanced Raman Spectroscopy (SERS), which he built upon C.V. Raman's discovery that the scattering of light by molecules could be used to provide information about a sample's chemical composition and molecular structure. The discovery of SERS completely transformed Raman Spectroscopy from one of the least sensitive to one of the most sensitive techniques in all of molecular spectroscopy. Today, SERS is used to study the chemical reactions of molecules in electrochemistry, catalysis, materials synthesis, and biochemistry.

Scanning Tunneling Microscope (1981)

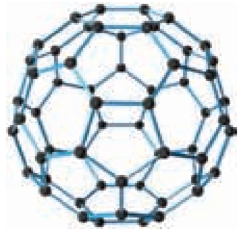
A STM in a Modern Lab

In 1981, the scanning tunneling microscope (STM) was invented by Gerd Binnig and Heinrich Rohrer at IBM's Research Laboratory in Zurich, Switzerland. This invention allowed scientists not only to observe nanoscale particles, atoms, and small molecules, but to control them. The STM helps researchers determine the size and form of molecules, observe defects and abnormalities, and discover how chemicals interact with the sample. Binnig and Rohrer won the Nobel Prize for this discovery in 1986, which quickly became standard equipment in laboratories throughout the world.

BuckyBall (1986)

Another nanotechnology breakthrough occurred in1985, when Richard Smalley, Robert Curl and graduate student James Heath at Rice University,

and Sir Harry Kroto at the University of Sussex discovered C60, a carbon nanoparticle shaped like a soccer ball. The unique molecule was named Buckminsterfullerene after the visionary American architect and engineer Buckminster Fuller who designed the geodesic dome. More commonly called a "buckyball", the molecule is extremely rugged, capable of surviving collisions with metals and other materials at speeds higher than 20,000 miles per hour.


"Elusive" Buckyballs

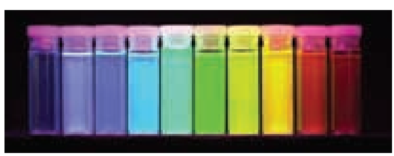
Atomic Force Microscope (1986)

Invented by Gerg Binnig and his colleague Christoph Gerber at IBM, San Jose, and Calvin Quate at Stanford University, the atomic force microscope or AFM, has the capability to view, measure, and manipulate materials down to fractions of a nano in size, including measurement of various forces intrinsic to nanomaterials. The AFM can make 3-D images of an object's surface topography with extremely high magnifications (up to 1,000,000 times).


Atomic Force Microscope

Discovery of Quantum Dots (1988)

In the early 1980s, Dr. Louis Brus and his team of researchers at Bell Laboratories made a significant contribution to the field of nanotechnology when they discovered that nano-sized crystal semiconductor materials made from the same substance exhibited strikingly different colours. These nanocrystal semiconductors were called quantum dots and this work eventually contributed to the understanding of the Quantum Confinement Effect, which explains the relationship between size and colour for these nanocrystals. Scientists have learned how to control the size of quantum dots making it possible to obtain a broad range of colours. Quantum dots have the potential to revolutionise the way solar energy is collected, improve medical diagnostics by

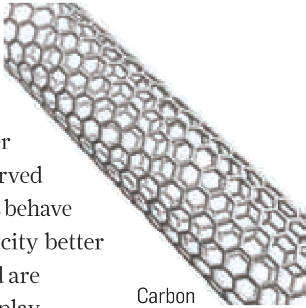

Different colours of quantum dots

providing efficient biological markers, and advance the development of optical devices such as light emitting diodes (LEDs).

Manipulation of Atoms (1990)

Using a Scanning Tunneling Microscope (STM), IBM researchers Donald Eigler and Erhard Schweizer were able to arranged individual Xe atoms on a surface. At IBM's Almaden Research Center in San Jose, California, they spelled out the company logo using 35 xenon atoms, which now hangs in IBM's STM Image Gallery.

Carbon Nanotubes (1991)



Carbon Nanotubes

Sumio Iijima of NEC is credited with discovering the carbon nanotube (CNT), although there were early observations of tubular carbon structures (several tubes nested inside each other) by others as well. Two years later Iijima, Donald Bethune at IBM in the US and others observed single-walled nanotubes just 1-2 nanos in dia. Nanotubes behave like metals or semiconductors, but can conduct electricity better than copper, can transmit heat better than diamond, and are among the strongest materials known. Nanotubes could play a pivotal role in the practical applications of nanotechnology if their remarkable electrical and mechanical properties can be exploited.

Moungi Bawendi of MIT

Synthesis of nano-Crystals (1993)

Moungi Bawendi of MIT invented a method for controlled synthesis of nanocrystals (quantum dots), paving the way for applications ranging from computing to biology to high-efficiency photovoltaic and lighting. Within the next several years, work by other researchers such as Louis Brus and Chris Murray also contributed methods for synthesising quantum dots.

IWGN (1998)

The Interagency Working Group on Nanotechnology (IWGN) was formed under the National Science and Technology Council to investigate the state of the art in nanoscale science and technology and to forecast possible future developments. The IWGN's study and report, "Nanotechnology Research Directions: Vision for the Next Decade' defined the vision for

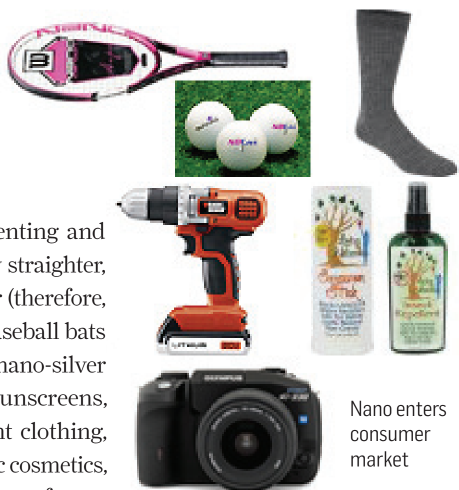
and led directly to formation of the U.S. National Nanotechnology Initiative in 2000.

Dip-Pen Nanolithography (1999)

A pivotal development in the constellation of nanotechnology tools was Dip-Pen Nanolithography or DPN. Invented in 1999 by Chad A. Mirkin (Rathmann Professor of Chemistry and Director of the Institute for Nanotechnology at Northwestern University), the concept is based upon a classic quill pen a 4,000 year old technology. Using an atomic microscope tip, DPN allows researchers to precisely lay down or "write" chemicals, metals, biological macromolecules, and other molecular "inks" with nano dimensions and precision on a surface. DPN has opened the door to credible nano-manufacturing techniques for smaller, lighter weight, faster, and more reliably produced electronic circuits and devices, high-density storage materials, and biological and chemical sensors.

Consumer Products (1999-2000)

By the turn of the twenty-first century, Consumer products making use of nanotechnology began appearing in the marketplace, including lightweight nanotechnology-enabled automobile bumpers that resist denting and scratching, golf balls that fly straighter, tennis rackets that are stiffer (therefore, the ball rebounds faster), baseball bats with better flex and "kick," nano-silver antibacterial socks, clear sunscreens, wrinkle- and stain-resistant clothing, deep-penetrating therapeutic cosmetics, scratch-resistant glass coatings, faster-recharging batteries for cordless electric tools, and improved displays for televisions, cell phones, and digital cameras.

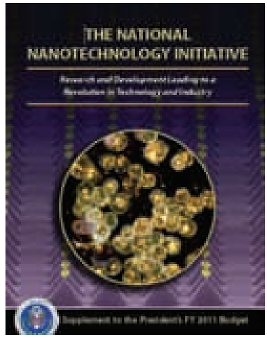


Nano enters consumer market

National Nanotech Initiative (2000)

In August 1999, the Interagency Working Group on Nanotechnology completed its first draft of a plan for an initiative in defining the art of nanoscale

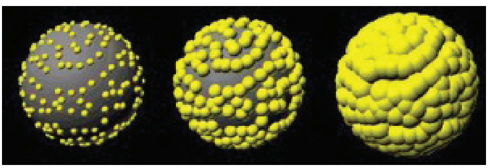
science and technology and forecasting possible future developments. As a result of this work, the Clinton administration raised nanoscale science and technology to the level of a federal initiative by including major funding as part of its 2000 budget submission to Congress, and officially referred to it as the National Nanotechnology Initiative (NNI). Congress funded the NNI for the first time in FY2001.



The National Nanotech Initiative

Gold Nanoshells (2003)

Naomi Halas, Jennifer West, Rebekah Drezek, and Renata Pasqualin at Rice University developed gold nanoshells, which when "tuned" in size to absorb near-infrared light, serve as a platform for the integrated discovery, diagnosis, and treatment of breast cancer without invasive biopsies, surgery, or systemically destructive radiation or chemotherapy.


Gold Nanoshells

Establishments in Europe (2004)

The European Commission adopted the Communication "Towards a European Strategy for Nanotechnology," COM(2004) 338, which proposed institutionalising European nanoscience and nanotechnology R&D efforts within an integrated and responsible strategy, and which spurred European action plans and ongoing funding for nanotechnology R&D. Britain's Royal Society and the Royal Academy of Engineering published "Nanoscience and Nanotechnologies: Opportunities and Uncertainties" advocating the need to address potential health, environmental, social, ethical, and regulatory issues associated with nanotechnology.

Nanoscale Car (2006)

James Tour and colleagues at Rice University built a nanoscale car made of oligo (phenylene ethynylene) with alkynyl axles and four spherical C60 fullerene (buckyball) wheels. In response to increases in temperature, the nanocar moved about on a gold surface as a result of the buckyball wheels turning, as

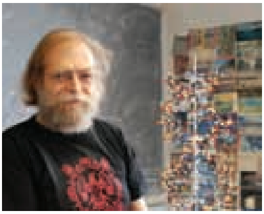
in a conventional car. At temperatures above 300°C it moved around too fast for the chemists to keep track of it!

Lithium-ion Battery (2007)

Angela Belcher and colleagues at MIT built a lithium-ion battery with a common type of virus that is non-harmful to humans, using a low-cost and environmentally benign process. The batteries have the same energy capacity and power performance as state-of-the-art rechargeable batteries being considered to power plug-in hybrid cars, and they could also be used to power personal electronic devices.

3D DNA Structures (2009–2010)

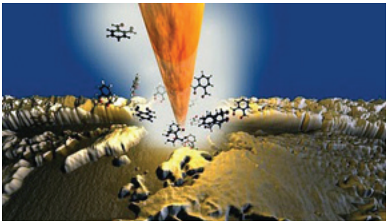
Nadrian Seeman and colleagues at New York University created several DNA-like robotic nanoscale assembly devices. One is a process for creating 3D DNA structures using synthetic sequences of DNA crystals that can be programmed to self-assemble using "sticky ends" and placement in a set order and orientation. Nanoelectronics could benefit: the flexibility and density that 3D nanoscale components allow could enable assembly of parts that are smaller, more complex, and more closely spaced.



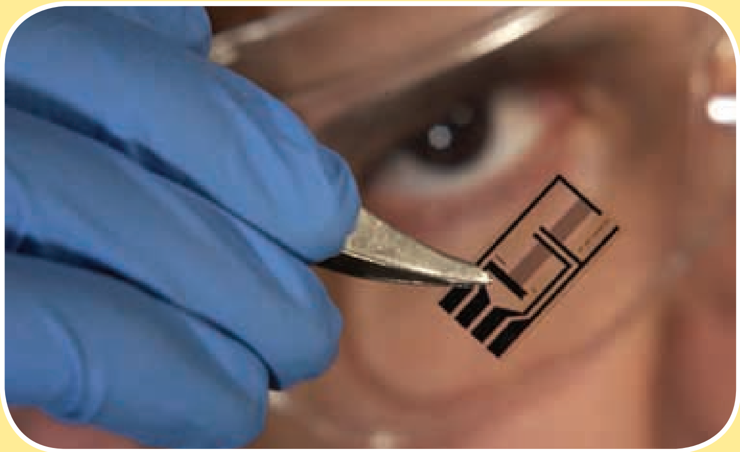
Inventor of DNA-like robotic nanoscale assembly devices

Smallest Relief Map (2010)

IBM used a silicon tip measuring only a few nanos at its apex (similar to the tips used in atomic force microscopes) to chisel away material from a substrate to create a complete nanoscale 3D relief map of the world one-one-thousandth the size of a grain of salt—in 2 minutes and 23 seconds. This activity demonstrated a powerful patterning methodology for generating nanoscale patterns and structures as small as 15 nanos at greatly reduced cost and complexity, opening up new prospects for fields such as electronics, optoelectronics, and medicine.



World's Smallest Relief Map



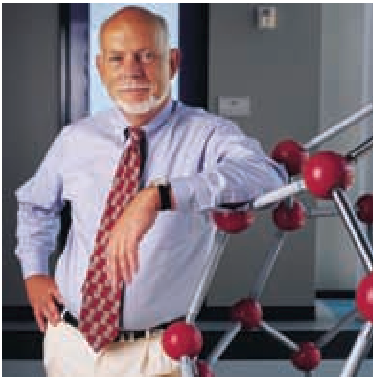
THE DEVIL'S IN THE DETAILS

In this section, we'll discuss three scientific papers, which will highlight the limitations that nanotechnology currently faces. These papers are spread over a decade and the transition in subject matter, also exhibits the paradigm shift in discussing the physical hard limitations of Nanotechnology. We will then try and demarcate the line between what nanotechnology is and what it definitely is not.

The first one by Richard E. Smalley is entitled "Of Chemistry, Love and Nanobots" and it addresses the question of how soon will we see the nano-scale robots envisaged by K. Eric Drexler and other molecular nanotechnologists. Richard E. Smalley is the Gene and Norman Hackerman Professor of Chemistry and Physics at Rice University. He received the 1996 Nobel Prize in Chemistry for the discovery of fullerenes.

In this paper, Smalley says that in recent years, it has become popular to imagine tiny robots (sometimes called assemblers) that can manipulate and build things atom by atom. Smalley conjures up a hypothetical situation as outlined below:

Imagine a single assembler: working furiously, this hypothetical nanorobot would make many new chemical bonds as it went about its assigned task, placing perhaps up to a billion new atoms in the desired structure every second. But as fast as it is, that rate would be virtually useless in running a nanofactory: generating even a tiny amount of a product would take solitary nanobot millions of years. (Making a mole of something—say, 30 grams, or about one ounce—would require at least 6 × 10^23 bonds, one for each atom. At the frenzied rate of 10^9 per second it would take this nanobot about 19 million years.) Although such a nanobot assembler would be very interesting scientifically, it wouldn't be able to make much on its own in the macroscopic "real" world.



Richard E. Smalley

Yet imagine if this nanobot was so versatile that it could build anything, as long as it had a supply of the right kinds of atoms, a source of energy and a set of instructions for exactly what to build. If the nanobot could really build anything, it could certainly build another copy of itself. It could therefore self-replicate, much as biological cells do. After a while, we'd have a second nanobot and, after a little more time, four, then eight, then 16 and so on.

Suppose each nanobot consisted of a billion atoms (109 atoms) in some incredibly elaborate structure. If these nanobots could be assembled at the full billion-atoms-per-second rate imagined earlier, it would take only one second for each nanobot to make a copy of itself. The new nanobot clone would then be "turned on" so that it could start its own reproduction. After 60 seconds of this furious cloning, there would be 260 nanobots, which is the incredibly large number of 1 × 10^18, or a billion billion. This massive army of nanobots would produce 30 grams of a product in 0.6 millisecond, or 50 kilograms per second. Now we're talking about something very big indeed!

Although it is a very pretty picture, Smalley asks us to consider how realistic this notion of self-replicating nanobots is. Atoms are tiny and move in a defined and circumscribed way — so as to minimize the free energy of their local surroundings. The electronic "glue" that sticks them to one another is not local to each bond but rather is sensitive to the exact position and identity of all the atoms in the near vicinity. So when the nanomanipulator arm of our nanobot picks up an atom and goes to insert it in the desired place, it has a fundamental problem. It also has to somehow control not only this new atom but all the existing atoms in the region. Even if the nanobot has an additional manipulator arm for each one of these atoms, our problems don't end here. The region where the chemistry is to be controlled by the nanobot is very, very small—about one nano on a side.

This constraint led Smalley to raise two fundamental difficulties or problem

- The fat fingers problem.
- The sticky fingers problem.

Because the fingers of a manipulator arm must themselves be made out of atoms, they have a certain irreducible size. There just isn't enough room in the

nano-size reaction region to accommodate all the fingers of all the manipulators necessary to have complete control of the chemistry

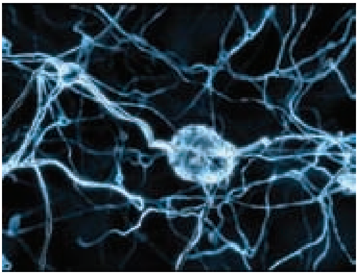
In his famous 1959 talk Nobel physicist Richard Feynman noted, "There's plenty of room at the bottom.", but Smalley jokes that there's not that much room. Manipulator fingers on the hypothetical self-replicating nanobot are not only too fat; they are also too sticky: the atoms of the manipulator hands will adhere to the atom that is being moved. So it will often be impossible to release this minuscule building block in precisely the right spot.

Smalley concludes that self-replicating, mechanical nanobots are simply not possible in our world. To put every atom in its place—the vision articulated by some nanotechnologists— would require magic fingers. Such a nanobot will never become more than a futurist's daydream.

Rupturing the Nanotech Rapture

The second paper we will be discussing was written by Richard A.L. Jones, who is a professor of physics at the University of Sheffield, in England, and senior nanotechnology advisor for the UK government's physical sciences and engineering funding agency. This paper entitled "Rupturing the Nanotech Rapture" was printed as a part of IEEE Spectrum's "Special Report: The Singularity" in June 2008. In this paper, Jones has presented an interesting critique of the room-temperature molecular nanomachinery and that nanobots, if possible, would be more "bio" than "bot".

Jones begins by attacking the expansive view of molecular nanotechnology, as touted by K. Eric Drexler in his 1992 book Nanosystems . In this book, Drexler envisaged nanostructures built from the strongest and stiffest materials available, using the rational design principles of mechanical engineering. The fundamental building blocks of this paradigm are tiny, rigid cogs and gears, analogous to the plastic pieces of a Lego set. The gears would distribute power from nanoscale electric motors and be small enough to assist in the task of attaching molecules to one another.


Special Report: The Singularity

Even if we can assume that an object's structure could easily be reduced to its molecular blueprint, Jone says that the first order of business would be figuring out how to translate macroscale manufacturing methods into nanoscale manipulations. For example, let's say you wanted a new pancreas. Your first major challenge stems from the fact that a single

human cell is composed of about 10^14 atoms and the pancreas you want has at least 80 billion cells, probably more. We could use a scanning tunneling microscope to position individual atoms with some precision, but to make a macroscopic object with it would take a very long time.

The theoretical solution, initially, was exponential manufacturing, which we have discussed earlier, that nanobots could construct objects on its own scale. For instance, it could make another assembler, and each assembler could go on to make more assemblers, resulting in a suite of assemblers that would combine forces to make a macroscopic object.

According to Jones this is a seductive idea, seemingly validated by the workings of the cells of our own bodies. As he points out the human body is composed of nothing but a host of sophisticated nanoassemblers: molecular motors that convert chemical energy into mechanical energy and membranes with active ion channels that sort molecules--two key tasks needed for basic nanoscale assembly. Cell biology also exhibits software-controlled manufacturing, in the form of protein synthesis. The ribosome is a remarkable molecular machine that can read information from a strand of messenger RNA and convert the code into a sequence of amino acids.The ribosome fulfils the functions expected of an artificial assembler--proof that complex nanoassembly is possible.

So if biology can produce a sophisticated nanotechnology based on soft materials like proteins and lipids, singularitarian thinking goes, then how much more powerful our synthetic nanotechnology would be if we could use strong, stiff materials, like diamond. And if biology can produce working motors and assemblers using just the random selections of Darwinian evolution, how much more powerful the devices could be if they were rationally designed using all the insights we've learned from macroscopic engineering.

But that reasoning fails to take into account the physical environment in which cell biology takes place, which has nothing in common with the macroscopic world of bridges, engines, and transmissions. As Jones point out, in the domain of the cell,

- Water behaves like thick molasses, not the free-flowing liquid that we are familiar with.
- The fluctuations of constant Brownian motion ceaselessly bombarded components by fast-moving water molecules and flex and stretch randomly.
- The van der Waals force, which attracts molecules to one another, dominates, causing things in close proximity to stick together. Clingiest of all are protein molecules, whose stickiness underlies a number of undesirable phenomena, such as the rejection of medical implants.

That begs the question on what's to protect a nanobot assailed by particles glomming onto its surface and clogging up its gears.

The watery nanoscale environment of cell biology seems so hostile to engineering that the fact that biology works at all is almost hard to believe. But biology does work--and very well at that. The lack of rigidity, excessive stickiness, and constant random motion may seem like huge obstacles to be worked around, but biology is aided by its own design principles, which have evolved over billions of years to exploit those characteristics. That brutal combination of strong surface forces and random Brownian motion in fact propels the self-assembly of sophisticated structures, such as the sculpting of intricately folded protein molecules.

In the end, rather than ratifying the"hard" nanomachine paradigm, cellular biology casts doubt on it. But even if that mechanical-engineering approach were to work in the body, there are several issues that, in Jones' view, have been seriously underestimated by their proponents;

1. The chemical properties of the cogs and gears. They are essentially molecular clusters with odd and special shapes, but it's far from clear that they represent stable arrangements of atoms that won't rearrange themselves spontaneously.
2. A second problem has to do with the power of surface forces and the high surface area anticipated for these nanobots. Researchers attempting to shrink existing microelectromechanical systems to the nanoscale have already discovered that the combination of friction and persistent sticking can be devastating.
3. We also don't know how an intricate arrangement of cogs and gears that depends on precision and rigidity to work will respond to thermal noise and Brownian bombardment at room temperature

All these complications when put together suggests that the range of environments in which rigid nanomachines could operate, if they operate at all, would be quite limited. If, for example, such devices can function only at low temperatures and in a vacuum, their impact and economic importance would be virtually nil.

Jones advocates more attention to "soft" nanotech, which is nanomachinery with similar design principles to biology -- the biomimetic approach -- as the most plausible means of making progress in nanotech. He asserts that human will reap major medical advances by radically reengineering existing microorganisms, especially in nanodevices that perform integrated diagnosis and treatment of some disorders

Intrinsic top-down unmanufacturability

The last paper we will be taking up was authored by Professor Mike Kelly- Centre for Advanced Photonics and Electronics, University of Cambridge – one of a leading nanotechnology scientist. This paper entitled "Intrinsic top-down

unmanufacturability" published on 21st April 2011 in IOP Publishing's journal Nanotechnologyargues that you cannot mass produce structures with a dia of three nanometres or less using a top-down approach.

The overall goal when entering nanotechnologies into the market is low-cost, high-volume manufacturability, but at the same time, the materials' properties must be highly reproducible within a pre-specified limit, which Kelly states cannot happen below the 3nm limit when trying to make arrays. According to Kelly, it doesn't matter if even the most modern forms of deposition (including epitaxy), e-beam or ultra-deep UV lithography and precision etching, the mainstay of microelectronics and optoelectronics fabrication, is being used; there are strict limits described below for which one-off fabrication is possible, but manufacture is not.

The top-down approach to manufacturing, which Kelly states is limited, uses external tools to cut and shape large materials to contain many smaller features. Its alternative, the bottom-up approach, involves piecing together small units, usually molecules, to construct whole materials – much like a jigsaw puzzle – however this process is too unpredictable for defect – free mass production of arrays.

Kelly used statistical evaluation of vertical nanopillars - that have been suggested for uses in sensors and displays - as an example to demonstrate his theory. He states that the proof comes in two stages. The first is due to the fact that when materials are mass produced on such a small scale there will be a lot of variation in the size of different components. As a result of this variation, the properties of the material will vary to an extent where the material cannot function

He refers to the paper "Nanowires: fabrication of Sub-10 nm metallic lines of low line-width roughness by hydrogen reduction of patterned metal–organic materials" which deals with quantum wires at 7 nm design rules showing that the conditions on uniformity within structures can be achieved that just reaches the levels required for silicon integrated circuit wiring. He concludes that the interface between manufacturability and unmanufacturability must be somewhere in between 3 and 7 nm. For silicon CMOS technology, the limit his higher, since reliable capacitors cannot be built smaller than the 10-15nm range.

However this paper doesn't address any physical limitations related to "bottom-up" manufacturing approaches, such as chemical or biological based molecular synthesis, which is another area of research for mass producing nanotechnology.

Professor Kelly says, "If I am wrong, and a counterexample to my theorem is provided, many scientists would be more secure in their continued working, and that is good for science."

What is it not?

To all the sci-fi fans out there, lets cut the fantasies and get down to the basics. We are going to tell you, in simple terms, what are the hard limits of Nanotechnology are and why some fantasies are simply not feasible.

Not Alchemy

Nanotechnology is not alchemy; it cannot turn lead into gold. That would require changing the structure inside atoms. Nanotechnology can only build objects using atoms. Rearranging atoms does change the properties of materials. The only difference between diamond and charcoal is the arrangement of its carbon atoms. But that does not mean we can make any material infinitely strong. True, we can make rockets of atomically perfect steel with no hidden cracks to give way over time. We could even build that rocket of diamond. But even diamond can be broken; it is only as strong as its chemical bonds. Nanotechnology does not give us control over chemistry.

Raw Materials

Nanotechnology could build diamond as easily as charcoal. But to do either, it would still need carbon atoms. The same principle would apply to anything we want to build. Although we still have a wealth of mineral resources on Earth, the scale of building with nanotechnology could conceivably outstrip that supply. In the long term, an endless supply of building materials exists in outer space, particularly in asteroids. But in the short term, scarcity of materials could be a limit on nanotechnology designs.

Random radiation

Natural radiation (fast moving particles that can penetrate objects) may not be our everyday concern. But it does cause damage at the atomic scale by disturbing the arrangement of atoms. For example, the rearrangement of atoms in human cells by radiation commonly results in cancer. If a nanotechnology machine is only 50 atoms across, radiation could significantly damage it. Even large scale machines built using nanotechnology might be in danger if they rely on a perfect arrangement of atoms to operate correctly.

Atomic magnets

Although it makes a great visual image, atoms cannot really be manipulated like building blocks. Conditions at the atomic level are much different than at human scale. Atoms behave somewhat like magnets. When they are brought too close together, overlap repulsion forces push them apart; at a distance, Van der

Waals Forces pull them together. And chemical bonding only allows atoms to be arranged in certain ways. None of these forces are noticeable at the macroscopic level, but they will restrict the way we can build with atoms.

Grainy Matter

You cannot always extrapolate common ideas, devices, or principles down to the nano-scale. Physical laws behave differently, so what works up here may not down there. Take a simple mechanical device such as a bearing. A common ball bearing consists of a ring of metal balls that slide around a circular track. To rotate smoothly, the touching surfaces must be very smooth. If we build an atomic counterpart made of round atoms, we cannot "smooth" the mating surfaces. The metal balls and the track are individual atoms, and you cannot subdivide an atom. Matter is "grainy" at the atomic level. In a real-world bearing, graphite or oil is used as a lubricant. In an atomic bearing, the graphite atoms would be as large as the bearing; no lubrication is possible. In short, we cannot assume that real world tools can be reduced to nano-scale. The physical laws are different.

Knowledge

According to some, what will stop nanotechnology is not physics but the limits of human comprehension. Nature is almost infinitely complex. And nanotechnology hopes to upstage nature; to intentionally design everything about an object that takes nature thousands of years to create using random experimentation (evolution). Consider a simple natural object: an apple. To "nano build" an apple, you would need an atomic map of an apple containing trillions of parts. You would then have to design proteins that could learn that map and place each atom perfectly. Understanding such a complex system may be beyond the limits of human comprehension.

If you doubt there are such limits, consider this. Humans have tried to plan a less complex, natural object: an economy. The Soviet-style central planning system was a massive failure by any standard, despite massive amounts of information and complete power. Economists in the West have had only limited success at just predicting economic conditions. Nanotechnology is a far more ambitious goal with far more information to be managed.

One might think that anything scientific has rules and can be learned eventually, but it is not so, No scientist can predict exactly how a cloud will move. The Navier-Stokes Equations, a mathematical approximation of how fluids like clouds should move, cannot be solved. The ultimate design limit on nanotechnology may be that some things just cannot be done because they are too complex.

LIFE 2.0

Nanotechnology is helping to considerably improve, even revolutionise, many technology and industry sectors: information technology, energy, environmental science, medicine, homeland security, food safety, and transportation, among many others. Described in this section is a sampling of the rapidly growing list of benefits and applications of Nanotechnology.

Nanotechnology is changing the world and the way we live, creating scientific advances and new products that are smaller, faster, stronger, safer, and more reliable. After about 20 years of steady progress in nanotechnology research and development, scientists all around the world have a much clearer picture of how to create nanoscale materials with properties never before envisioned. Described below is a sampling of the rapidly growing list of benefits and applications of nanotechnology-

The Energy Crisis

The biggest application of nanotechnology will in helping humans meet what is arguably the biggest global challenge of the 21st century: providing a growing human population with reliable, clean, affordable energy. The need for energy bears on all other quality- of-life issues, including healthcare, national security and availability of water resources. If scientists do succeed in domesticating atoms, they could potentially revolutionize how we generate, store, distribute and use energy.

The era of cheap fuels is over. There is no two ways about it – and a mere

Solar cells using Nanotechnology

glance at the prices at your local gas station will confirm this. The reason behind this is the huge mismatch between the current energy demand and supply – and this gap is only growing wider. The demand for energy is expected to grow as China and India industrializes; at the same time, global oil production is declining, while the climatic effects of burning fossil fuels have become more pronounced. This brewing crisis will probably lead to more political instability and warfare and it would be fair to say that energy has become a "gun-to-the-head" issue.

The only good that has come out of this energy crisis is that it has spurred scientists to use nanotechnology to find energy alternatives, and to find ways to manufacture everything, including nanoproducts, using less energy. But it is very important to come to grips with the fact that Nanotechnology alone cannot solve the energy problem which is more than Nanotech can encompass. To a world which is still evolving a national energy policy, it is downright difficult to even figure out where Nanotechnology will fit in.

Turning crude oil into diesel fuel

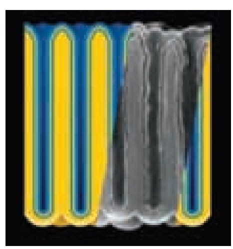
Even though we don't precisely how Nanotechnology fits in, it is easy to visualize the various ways, it can potentially contribute to energy solutions. Many research groups and private companies are already exploring a variety of alternative energy sources, such as solar power, wind power, nuclear fusion, hydrogen fuel cells and biofuels. Slowly but surely new nanotools, knowledge and skills are being gradually absorbed and applied in numerous energy-related technologies, from light bulbs to fuel catalysts to batteries. Some of these advances might occur quietly and unspectacularly, but even small improvements could add up to big savings in energy usage.

To begin a journey toward solutions, the energy problem is divided into well-defined technical challenges. These include efficient energy conversion, efficient energy storage, efficient energy transmission and efficient energy use.

1. **Efficient energy conversion –** There is no dearth of energy. It is all around us. But it is often inaccessible or in a unusable form. Currently, we extract chemical energy from coal, oil and natural gas because these energy-rich materials come in convenient forms. These are also relatively easy to transform into a range of products, including formulated fuels, and into electricity that can be widely distributed by power lines. As fossil fuels grow scarce and increase in value, nanotechnology could be used to reduce losses during energy conversion. For instance, nano-engineered catalysts could improve the conversion of crude oil into various petroleum products, as well as the conversion of coal into clean fuels for generating electricity. Over the long term, the attention is likely to shift to the improvement of our ability to convert sunlight into electricity, the easiest form of energy to use. Common commercially available solar cells have an efficiency of about 12 percent; some laboratory models achieve 30 percent. Researchers are testing many different ways to boost energy conversion by fine-tuning the material properties in solar cells, and it is quite likely that the problem will be solved using nanotechnology. Some prototypes have embedded carbon nanotubes in them, while others take advantage of nanocrystals or clusters of atoms called quantum dots. However, we still need to learn a lot more about the fundamental processes behind various energy conversions, including sunlight to electricity, heat gradients to electricity and nuclear fusion to electricity.

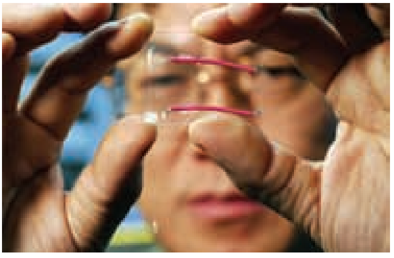

Solar Panels

2. **Efficient energy storage –** The next step after efficiently converting energy into a usable form, is to store it efficiently so that we can use it whenever we need it. In the near term, nanotechnology could be used to create appliances and other products that can store energy more efficiently—that is, take up charge and hold it over time. Many research groups are working on better batteries, often using engineered nanomaterials. Better batteries might make it possible to store energy that is generated in a widely distributed way, such as within consumer products. That would eliminate the need to ship energy across thousands of miles and solve the


Energy Storage

problem of losses during transport. There is a need to develop small-scale energy-storage units that could be located in people's homes, and give us an extremely robust, terrorist-resistant, delocalized electrical-energy system. Such an appliance might be developed using nanotechnology. With energy-storage units that are small, efficient and affordable, communities could buffer themselves against fluctuations in energy availability, such as when the sun stops shining or the wind stops blowing.

3. **Efficient energy transmission –** In today's world, energy is not typically generated right where it is needed. Hence the need for energy transmission. Nanotechnology could be used to create new kinds of conductive materials that lose very little energy as electricity moves down the line. Many research groups are investigating whether nanowires and nanocoatings could reduce losses in electrical-transmission lines. "Self-cleaning" nanomaterials might be used to keep ice from accumulating on power lines—something that leads to disruptions in power in areas of cold winters. In the longer term, the need for efficient energy transmission might disappear if energy is converted and stored locally.
4. **Efficient energy use -** Nanotechnology could lead to breakthroughs that indirectly conserve large amounts of fossil fuels. A large portion of the oil budget goes toward producing nitrogen fertilizers for agriculture. If scientists could find a way to fix nitrogen from the atmosphere, we could save huge amounts of fuel. Nanomanufacturing might also enable us to make all kinds of products using less energy. For instance, nanosensors might be used to track energy use and help minimize waste.


An Energized Future?

We only need to look around for ideas on harnessing energy. These ideas will come from studies of living creatures—for instance, from learning about the way plants generate energy from sunlight and the way animals produce energy broadly throughout their bodies using their cells' mitochondria. Nanotools might help researchers create artificial life forms that resemble simple bacteria and then employ these creatures to produce fuel for.

Eventually, nanotechnology will lead to radical transformations in energy technologies. We only need to wait and see just how it will come about.

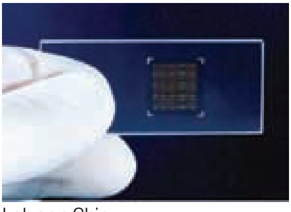
Medicine and Diagnostics

The advent of Nanomedicine

One of the hottest areas of research is nanomedicine, and Nanotechnology stands a good chance of revolutionizing the practice of medicine. If scientists domesticate atoms and molecules, they could harness them for a wide range of medical purposes. For one thing, they could create novel nanostructures that serve as new kinds of drugs for treating common conditions such as cancer, Parkinson's and cardiovascular disease. They could also engineer nanomaterials for use as artificial tissues that would replace diseased kidneys and livers, and even repair nerve damage. Moreover, they could integrate nanodevices with the nervous system to create implants that restore vision and hearing and build prosthetic limbs that better serve the disabled.

Medical applications of nanotechnology—more so than energy applications—are already rapidly developing. Many companies, including pharmaceutical giants, medicaldevice makers, biotech companies and start-up ventures, are now exploring and using nanotechnology for healthcare applications. In fact the U.S. Food and Drug Administration (FDA) approved the first drug to employ nanotechnology, more than six years ago. Called Abraxane, this nanomedicine was made by loading the drug Taxol into nanoparticles of albumin, a protein that is plentiful in human serum. In this formulation the drug appears to be less toxic than regular Taxol and more effective in treating metastatic breast cancer. The first-generation nanomedicines are mostly reformulations of existing drugs, and they often use new methods of delivery within the body. Researchers are currently testing everything from buckyballs to nanocapsules to dendrimers as vehicles for efficiently ferrying drugs in the body, particularly for delivering chemotherapy agents to tumors.

The first order of business in the application of nanotechnology in the medicine sector is to come up with faster, cheaper diagnostic equipment. For instance, a diagnostic kit that employs gold nanoparticles is being tested in hospitals for use in detecting prostate cancer early, at a stage when the numbers of protein biomarkers in the blood are quite low. The lab-on-a-chip will be able to analyze a patient's ailments in an instant, providing point-of-care testing and drug application. New contrast agents will float through the bloodstream, lighting up problems such as tumors with incredible accuracy. Diagnostic tests will become more portable, providing time-sensitive diagnostics out in the field on ambulances.

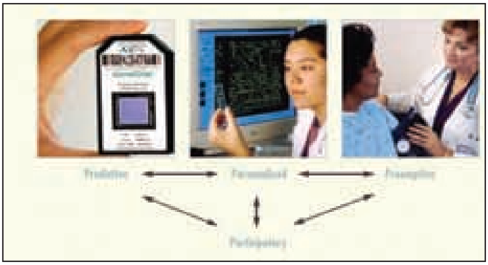

Lab on a Chip

Newborn children will have their DNA quickly mapped, pointing out future potential problems, allowing us to curtail disease before it takes hold. Researchers have already successfully engineered a variety of scaffolds made from nanotubes and nanofibers that can be used to grow lifelike networks of cells from the liver, bladder, kidney, bones and cardiovascular system. These artificial tissues could be developed into new therapies for patients with diseased or damaged organs.

Further out into the future nanotechnology, can be expected to aid in the delivery of just the right amount of medicine to the exact spots of the body that need it most. Nanoshells, approximately 100nm in dia, will float through the body, attaching only to cancer cells. When excited by a laser beam, the nanoshells will give off heat — in effect, cooking the tumor and destroying it. Nanotechnology will create biocompatible joint replacements and artery stents that will last the life of the patient instead of having to be replaced every few years. Although the research is still exploratory, several groups of scientists are beginning to build novel nanostructures that mimic complex biomolecules. Some of these appear to have regenerative powers and might lead to therapies for untreatable conditions such as Alzheimer's, nerve injury and brain damage from stroke.

A suitable match?

Quite a few decades from now, it will probably become possible to create interfaces between the nervous system and electronic devices. These nanoscale links would make it possible to essentially "plug in" human-made machines to the body—for instance, prosthetic legs that truly function like one's own. With the knowledge of effectively stimulating muscles and advances in robotics and information science, it will become possible to generate intelligent walking properties. Interfaces between neurons and electronic devices would also make it possible to



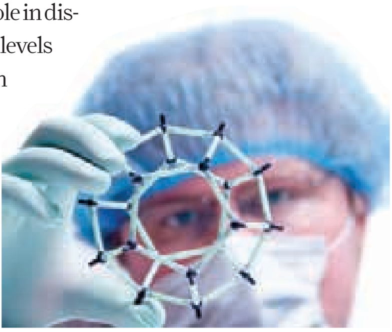
The four revolutions

develop a wide variety of brain implants. At first, these would undoubtedly serve to improve treatment of diseases with root causes in the brain, such as Parkinson's disease and epilepsy. Implants might also be developed to replace parts of the brain damaged by stroke or injury, or to fine-tune imbalances that cause severe depression and other mental illnesses. Eventually, implants might be used to enhance normal brain function— for example, to boost memory and learning. Of course, at each step there is likely to be a lot of soul searching and debate about the ethics of these interventions and about what it means to be human.

Scientists predict four distinct revolutions in medicine, and envision that nanotechnology could play a pivotal role in driving any or all of them. Nanotechnology could be used to make medicine more predictive, preemptive, personalized and participatory (regenerative).

1. **Predictive medicine-** In this vision nanotechnology would help doctors predict the major diseases that an individual is likely to develop. The goal would be to routinely and cheaply analyze several hundred substances in a patient's blood and estimate disease risks with a relatively high degree of accuracy. This panel of tests would provide a window on a person's overall state of health.
   As mentioned earlier, several research groups working on developing a "lab-on-a-chip" device—using nanotechnology—to perform a comprehensive analysis of a drop of blood. The blood analysis would alert the doctor to early precursors of disease that reflect both genetic predispositions and environmental factors, such as diet, exercise, stress and exposure to air pollution. Predictive medicine sounds incredibly promising, but developing such a comprehensive test might prove to be exceedingly challenging.

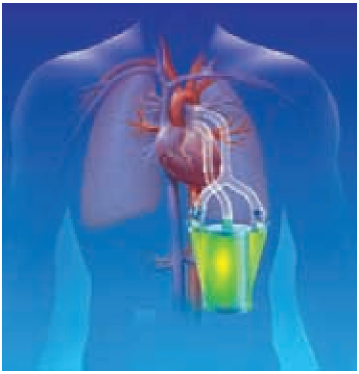
- First, researchers would have to identify the 200 or so most important disease biomarkers.
- Next, although scientists would not have to understand every last detail about each biomarker and its role in disease, they would have to know how the levels of each biomarker vary normally and in various stages of disease.
- Patterns will have to be identified by trolling though huge amounts of data collected from a road population sample. And the computations might require fancy mathematical tools that have not yet been invented.


Nanomedicine

The complexities don't end here. For

instance, a genetic test can tell you that you are at high risk for Huntington's disease, but you cannot do much to stop the progression of this incurable neurological disease. There is a consensus, however, that one of the biggest impacts of nanotechnology will be rapid DNA sequencing. New nanopore devices are poised to make complete genome sequencing rapid, cheap and widely available. That means it will be possible for individuals to find out the sequences of all their genes, including those linked to disease. However it remains to be seen whether or not the public will embrace personal genomic sequencing, and whether or not it might pave the way for predictive medicine or derail it.

2. **Preemptive medicine -** This vision focuses more on early intervention, to help doctors detect treatable diseases earlier so that they can help patients preempt the full-blown development of illness or at least manage it effectively over a lifetime. Nanotechnology can enhance the development of more- sensitive diagnostic tests, as well as devices for health monitoring and disease management. Diabetes care is one obvious and important area that would stand to benefit from it. Consider that if new, nano-based diagnostic tests could detect the earliest stages of insulin resistance; one could make changes in one's diet and exercise to slow the progression of the disease. A health-monitoring device at home could help one maintain one's regimen by providing positive feedback on your blood sugar levels. It would also help one manage the dosage and timing of insulin intake more effectively. Similarly, preemptive medicine might be used to help a large portion of the population more effectively deal with cardiovascular disease and hypertension. This model could be expanded and used to manage many chronic diseases—say, for example, lupus or arthritis— as new diagnostic tests, monitoring capabilities and therapies became available.



Never seen before cures,

3. **Personalized medicine -** This vision aims to make medicine more personalized by using information about an individual, to specifically tailor his or her treatment. A doctor has a much greater chance of coming up with an effective medical strategy if he or she knows something about a patient's disease subtype, metabolism (particularly as it relates to drugs), liver status and risk

for other diseases, for example. Nanotechnology could provide new tools for gathering detailed information about variations in disease states and about unique paras of treatment. Perhaps more important, nanotechnology could spur the personalized-medicine revolution by helping bring about real-time, sensitive monitoring of drug therapies. With more frequent feedback, a doctor could easily adjust drugs and dosages to personalize a patient's therapy. Indeed, treatments are expected to become more complex in the future. For instance, a doctor might prescribe a cocktail of several different drugs in calculated proportions—perhaps 10 percent of drug A, 50 percent of drug B and 40 percent of drug C. Nano-based monitoring devices could give doctors the ability to adjust the drug cocktail to suit the individual patient.

4. **Participatory (regenerative) medicine –** The focus of this vision is to regenerate a part of the body that has been injured or has deteriorated as the result of disease, genetic defects or normal aging. Although regenerative medicine is generally associated with stem cells, nanotechnology could also lead to radically new treatments for spinal cord injury, macular degeneration, type 1 diabetes and other dysfunctions. Whether stem cells can be coaxed to rebuild tissues and restore function remains to be seen, but an equally promising approach is to employ nanostructured artificial tissues. It is still early, but many laboratories are experimenting with a wide variety of nanomaterial scaffolds that can be infused with cells to form artificial tissues, such as bone and liver. It appears possible to repair damaged nerves by injecting them with nanomaterials that form bridge-like lattices. Other nanostructures show promise as foundations for growing three-dimensional networks of blood vessels. Regenerating damaged tissues is one approach, but lost function might also be restored using nano-enhanced replacement parts for the body—devices that hook right into the nervous system. Although science fiction writers and moviemakers have explored this idea in many colorful ways, it could indeed become reality as the result of rapid advances in nanotechnology, microelectronics, robotics, information science and neuroscience.


Fountain of youth?

So it is quite fair to say that the sky seems to be the limit of what might one day be accomplished with nanostructured artificial tissues and nano-enhanced prosthetic devices. In the meantime, researchers developing them will have to

grapple with concerns about biocompatibility—that is, making sure that the materials are not toxic and do not trigger harmful immune reactions. Hopefully these challenges could be surmounted and that nanotechnology would help bring about a golden era of diagnostics and medicine.

Clean Water

In first world countries, the potential application of Nanotechnology focuses more on energy and medicine, but in the third-world countries, the focus shifts to water resources. After all it is an essential part of life and is crucial to our standard of living, greatly affecting our ability to maintain health, grow food and build vibrant industries. Nanotechnology has the potential to revolutionize clean-water technologies by improving water purification, preventing water pollution and cleaning up tainted groundwater, lakes and streams.

According to the United Nations, one-fifth of the world's population lacks access to safe drinking water. Climate change is expected to further strain water resources by shifting precipitation patterns and causing severe drought in some regions. Furthermore this problem is not restricted to the under-developed and developing countries only; much of the central United States is experiencing record-breaking drought. Water woes even plague communities with plentiful supplies, but poor water quality. Old pipes leaching unsafe amounts of lead into the water, groundwater contaminated by perchlorate and other contaminants, render them unfit for use.

Nanotechnology can be exploited to boost the availability of clean water. Nanotechnology could be used to determine water cleanliness, enable the filtration of dirty water, reduction of water use, and cleaning up polluted bodies of water. N nanomaterials could be harnessed to enhance existing water-purification processes as they have a high surface area and can be chemically tailored. Nanoparticles show great potential as sorbents, materials that latch on to pollutants and pull them out of solution. For instance, multi-walled carbon nanotubes have been shown to take up lead, cadmium and copper more effectively than does activated carbon, a commonly used sorbent. Some nanoparticles also act


The need of the Hour.

as potent catalysts and could be used to render pollutants harmless. Nanosize iron, for example, can detoxify organic solvents, such as trichloroethylene. Other nanoparticles that are bioactive, such as silver and magnesium oxide, can kill bacteria and might be used in place of chlorine to disinfect water.

Nano-engineered membranes and filtration devices could be used to detect and remove viruses and other pollutants that are difficult to trap using current technologies. For instance, a preliminary technique employs imprinted polymer nanospheres to detect pharmaceuticals—a kind of pollution coming from households that is difficult to spot in waterways and was only recently discovered. Such nanoscale sensors might be helpful for real-time monitoring of these pollutants—everything from chemicals in Prozac to hormones in birth control pills—at water-treatment plants and industrial sites. Eventually, "smart" membranes with specifically tailored nanopores might be designed to both detect and remove such pollutants. With greater ability to filter out unwanted materials, industrial wastewater— and even the ocean—could become available to boost the supply of clean water.

The short term goals for Nanotechnology based clean water technologies would be the development of new techniques for remediation of water pollution. In another decade or so, nanotechnology is expected to have an impact on water treatment, beginning with nano absorbents and bioactive nanoparticles that could be integrated into existing purification systems. Before being used for water treatment, these nanomaterials would need to be evaluated for safety, including examining their toxicity, their transport, and their fate in the environment. Some of these visions are outlined below:

1. **Desalination -** One way to expand the availability of drinking water in coastal communities is to turn to the sea and developing technologies for removing salt from seawater. The trouble with desalination is that it currently requires a lot of energy, so it is costly and all but guaranteed to grow more expensive in the future. There is a critical need to design alternative desalination methods that are more efficient. The aim is to develop smart membranes with antimicrobial surfaces and embedded sensors that can automatically adjust membrane performance. Nanotechnology is likely to play an important role in meeting that challenge.


Desalination of sea water

2. **Personal water treatment –** It is really necessary to have new technologies to treat water at its point of use. People will need to be equipped with devices that enable them to purify water at the tap, at the well, or in their residences. The idea is to dismantle the current model of centralized water-treatment plants and to replace it with small, strategically placed treatment systems that meet the water needs of population clusters. Such satellite treatment systems would be particularly useful in developing countries like India, where big plants are still rare and there is a tremendous need for cost-effective ways to bring clean drinking water to the masses. These satellite treatment systems could be customized to remove the specific contaminants found in a local water source. Nanosorbents, nanocatalysts, smart membranes, nanosensors and other kinds of nanotechnology could serve as the basis for new, small scale water treatment systems. The goal of personal water treatment might actually prove easier to reach than the goal of integrating nanotechnology into existing centralized water treatment plants operated by public utilities.
3. **Emerging pollutants.** Unfortunately, new kinds of pollutants are being continually discovered in water resources, even while we still deal with old problems such as lead and pesticides. Waterways now contain trace quantities of personal-care products such as sunscreens, medicines of all kinds and flame retardants and plastic residues that slough off consumer products. Some of these materials have been shown to have deleterious effects on fish and other wildlife, and they might also cause subtle health effects in people. Nano-enhanced water filtration could be developed to target these new contaminants. Advanced methods of water purification using nanotechnology might prove to be the only viable strategy for keeping a wide variety of nanomaterials off the growing list of emerging pollutants.

Computers

The history of computers and computer technology thus far has been a long and a fascinating one, stretching back more than half a century to the first primitive computing machines In the past twenty years, there has been a dramatic increase in the processing speed of computers, network capacity and the speed of the internet. These advances have paved the way for the revolution of fields such as quantum physics, artificial intelligence and nanotechnology. These advances will have a profound effect on the way we live and work, the virtual reality we see in movies like the Matrix, may actually come true in the next decade or so.

In the past twenty years, there has been a dramatic increase in the processing speed of computers, network capacity and the speed of the internet. These

advances have paved the way for the revolution of fields such as quantum physics, artificial intelligence and nanotechnology. These advances will have a profound effect on the way we live and work, the virtual reality we see in movies like the Matrix, may actually come true in the next decade or so.

Let us take a peek into what the future might hold for our computing devices.

1. Nanocomputers

Nanocomputer is the logical name for a computer smaller than the microcomputer, which is smaller than the minicomputer. Technically speaking, it is a computer whose fundamental parts are no bigger than a few nanos. For comparison, the smallest part of current state-of-the-art microprocessors measures 45 nm as of February 21, 2007. But this is all set to change very soon.

1st Novemeber 2011. According to a group of researchers calling themselves the Nanocomputer Dream Team, that's the day they'll unveil a revolutionary kind of computer, the most powerful ever seen. The team includes Bill Spence, publisher of Nanotechnology magazine and over 300 enthusiasts with diverse backgrounds - engineers, physicists, chemists, programmers and artificial intelligence researchers.

The most promising idea is rod logic, invented by nanotechnology pioneer Eric Drexler, now chairman of the leading nano think tank The Foresight Institute. Rod logic uses stiff rods made from short chains of carbon atoms. Around each rod sits a knob made of a ring of atoms. The rods are fitted into an interlocking lattice, where each rod can slide between two positions, and be reset by a spring made of another few atoms. This arrangement has already been used to achieve the effect of a conventional electronic transistor, where the flow of current in one wire is switched on and off by current in a different wire. Once you have transistors, you can build a NAND gate. From NAND gates you can construct every other logic element a computer needs.


The future of computers

1.1. Electronic Nanocomputers

Given our experience of working with electronic computing devices, it is highly likely advances in nanocomputing technology are likely to come from this direction, thus making the electronic nanocomputers the first ones to come out. Electronic nanocomputers would operate in a manner similar to the way present-day

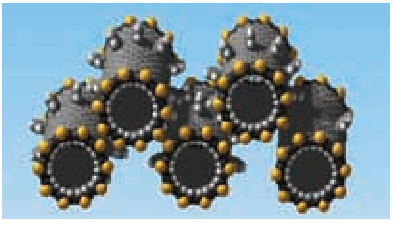
microcomputers work. The main difference is one of physical scale. More and more transistors are being squeezed into silicon chips with each passing year and ICs are evolving with ever-increasing storage capacity and processing power. We are still not close to pushing the ultimate limit to the number of transistors per unit volume, which is imposed by the atomic structure of matter.

Although there has been an exponential increase in the density of transistors on integrated-circuit computer chips over the past 40 years, there has been no fundamental change in the operating principles of the transistor. They still operate using small electric fields imposed by tiny charged metal plates to control the mass action of many millions of electrons. Electronic nanocomputers are expected to continue representing information in the storage and movement of electrons, but they will be created through microscopic circuits using nanolithography.

Nanolithography is a term used to describe the branch of nanotechnology concerned with the study and application of a number of techniques for creating nanoscale structures. It is used during the fabrication of leading-edge semiconductor integrated circuits (nanocircuitry) or nanoelectromechanical systems (NEMS). Dip-pen nanolithography can achieve very small sizes, but cannot currently go below 40nm.However new nanolithography technologies are constantly being researched and developed, leading to smaller and smaller possible sizes.

1.2. Mechanical Nanocomputers

Pioneers as Eric Drexler proposed as far back as the mid-1980's that nanoscale mechanical computers could be built via molecular manufacturing through a process of mechanical positioning of atoms or molecular building blocks one atom or molecule at a time, a process known as "mechanosynthesis." His proposal for mechanical nanocomputer, took inspiration from Charles Babbage's analytical engines of the 19th century. However mechanical nanocomputer technology has sparked controversy and some researchers even consider it unworkable. All the problems inherent in Babbage's apparatus, according to the naysayers, are magnified a million fold in a mechanical nanocomputer. Nevertheless, some futurists are optimistic about the technology, and have even proposed the evolution of nanorobots that could operate, or be controlled by, mechanical nanocomputers.



Mechanosynthesis

1.3. Chemical Nanocomputer

In general terms a chemical computer is one that processes information in by making and breaking chemical bonds and it stores logic states or information in the resulting chemical (i.e., molecular) structures. In a chemical nanocomputer computing, would be based on chemical reactions (bond breaking and forming) and the inputs will be encoded in the molecular structure of the reactants and outputs extracted from the structure of the products. In order to create a chemical nanocomputer, engineers need to be able to control individual atoms and molecules so that these atoms and molecules can be made to perform controllable calculations and data storage tasks. The development of a true chemical nanocomputer will likely proceed along lines similar to genetic engineering.


The future of biological Nanocomputers

1.4. Biological Nanocomputer

In a manner of speaking biological Nanocomputer already exist in Nature. All we need to do is figure out a way to replicate it. These naturally occurring systems are largely uncontrollable by humans and that makes artificial fabrication or implementation of this category of "natural" biochemically based computers seems far off because the mechanisms for animal brains and nervous systems still are poorly understood.

1.5. DNA Nanocomputer

In 1994, Leonard Adelman took a giant step towards a different kind of chemical or artificial biochemical computer when he used fragments of DNA to compute the solution to a complex graph theory problem. DNA nanocomputers would use DNA to store information and perform complex calculations. DNA has a vast amount of storage capacity that enables it to hold the complex blueprints of living organisms. The storage capacity of a single gram of DNA can hold as much information as one trillion compact discs.

1.6. Quantum Nanocomputer

A quantum computer uses quantum mechanical phenomena, such as entanglement and superposition to process data. Quantum computation aims to use the quantum properties of particles to represent and structure

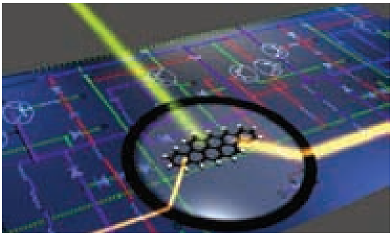
data using quantum mechanics to understand how to perform operations with this data. A quantum nanocomputer would work by storing data in the form of atomic quantum states or spin. Technology of this kind is already under development in the form of single-electron memory (SEM) and quantum dots.

The quantum mechanical properties of atoms or nuclei allow these particles to work together as quantum bits, or qubits. These qubits work together to form the computer's processor and memory and can can interact with each other while being isolated from the external environment and this enables them to perform certain calculations much faster than conventional computers.

2. Optical Computers

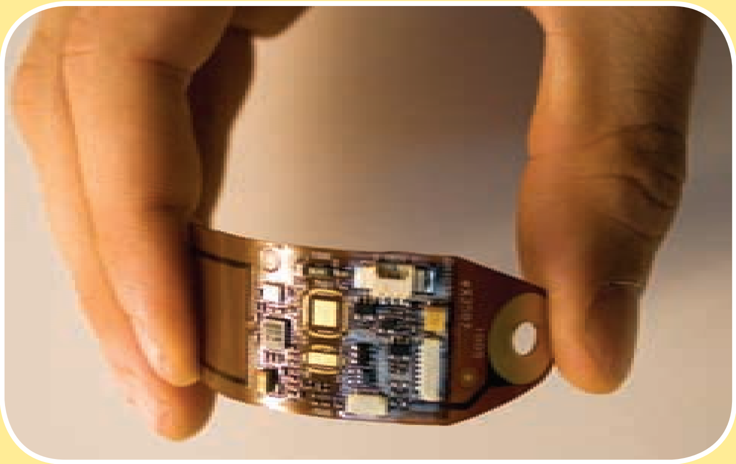
An optical computer (also called a photonic computer) is a device that performs its computation using photons of visible light or infrared (IR) beams, rather than electrons in an electric current. In most modern computers, electrons travel between transistor switches on metal wires or traces to gather process and store information. The optical computers of the future will instead use photons traveling on optical fibers or thin films to perform these functions.

Currently scientists are focusing on developing hybrids by combining electronics with photonics. This approach appears to offer the best short-term prospects for commercial optical computing, since optical components could be integrated into traditional computers to produce an optical/electronic hybrid NASA. But optoelectronic devices lose about 30% of their energy converting electrons into photons and back and this switching process slows down transmission of messages



Application of Photonics

These hybrid devices will eventually lead to all optical computer systems. All-optical computers eliminate the need for switching. These computers will use multiple frequencies to send information throughout computer as light waves and packets thus not having any electron based systems and needing no conversation from electrical to optical, greatly increasing the speed.



THE GOOD, THE BAD AND THE UGLY

Over the next 20 years, Nanotechnology will touch the life of nearly every person on the planet. But like many of the best advancements, it's not without risk. Here we present to you some of the future scenarios – both, promising and terrifying - that nanotechnology might bring about.

The potential benefits of Nanotechnology are mind boggling and brain enhancing. The future of Nanotechnology is completely uncharted territory. It is almost impossible to predict everything that nanoscience will bring to the world considering that this is such a young science.

There is the possibility that the future of nanotechnology is very bright, that this will be the one science of the future that no other science can live without. There is also a chance that this is the science that will make the world highly uncomfortable with the potential power to transform the world. Here we present to you some of the future scenarios-both promising and terrifying- that nanotechnology might bring about.

Fountain of Youth

In June 2010, Thomson Reuters, one of the world's leading sources of intelligent information for businesses and professionals, came out with a report entitled "Can Nanotech Unlock the Fountain of Youth?" The report claimed that in its eternal pursuit of the fountain of youth, the beauty industry has zeroed in on Nanotechnology as its wonder child. This innovation frontier is being used in creams that make wrinkles vanish; shampoos that deliver vitamins deep into the cellular

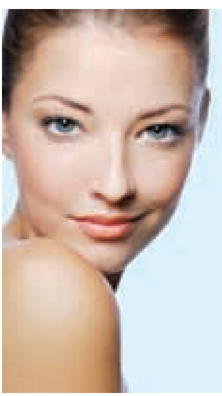
A mythical journey

structure of a hair and sunscreens that penetrate the skin to block UV rays, bringing us inch by inch closer to the elusive goal of eternal youth.

There are currently over 1,000 products on the global market that claim to contain a nanomaterial as a key ingredient, and the industry is expected to continue growing. According to the "Project on Emerging Nanotechnologies" global research and development investment totals nearly $9 billion a year. By 2015, it is estimated that consumer products with nanotechnology applications will value $1 trillion on the world market.

Amorepacific is a point in example. This company leads the US Market, with over 50 products that claim to use nanotechnology as a point of differentiation to compete with other products in the global marketplace. After extensive research, Amorepacific chose to develop and apply nanodelivery technology for the vast majority of their skin care products because the technology offered the most effective means available to deliver active ingredients to the skin. Through various nanotechnologies, such as nanocapsulation and nanoemulsion, Amorepacific are making their customers feel their skin being repaired with better moisturization, enhanced smoothness and improved elasticity.

The report tracked unique inventions published in patent applications and granted patents from 2003 to 2009, along with trademark data from 2000 through 2009, to identify the companies and areas of nanotechnology innovation showing the sharpest growth in this industry. The report laid bare the following conclusions –



The quest for flawless beauty

1. **Overall Nanotechnology Growth:** The volume of innovative patents involving nanotechnology in beauty-and-personal-care items more than doubled over the last seven years, growing from 181 patents in 2003 to 367 in 2009.

2. **Specialty Chemical Companies Stake Claim:** While L'Oreal and Amorepacific were early innovators in the development of nanotech-based beauty products, a great deal of new innovation in the field comes from companies that one would not tradition-

ally associate with the cosmetics industry, including Fujifilm and BASF. Of 367 unique inventions filed in 2009, 10 were by Fujifilm; 9 were by BASF and 7 were by Amorepacific.

3. **"Nano" Trademarks:** From 2000 through the end of 2009, a total of 217 personal-care brands that incorporate the term "nano" were trademarked in the United States, United Kingdom, Canada, European Community and WIPO. In 2009, 124 patents had been filed with WIPO, more than double the 51 patents filed in the United States. China and Korea round out the top three, following closely behind with 50 patents each.

The report predicts that the popularity and use of nanotechnology in personal-care products is certain to expand in the coming years, especially as consumers begin to experience the benefits of this technology and associate it with looking younger and feeling rejuvenated.

However, the dream conjured up by Thomson Reuters has also run into criticism, as just being an advertisement of their IP Market Reports, and failing to mention potential health and safety risks that are being raised by scientists. So let's break down the mystery of how exactly beauty products make use of nanotechnology and what are the potential risks involved.

How does it work?

The epidermis (top layer of skin) on the face is about 0.2 millis thick. Although it seems like a minuscule quantity, we need to look at this dimension from the point of view of the ingredients in the skin care product. As far as they are concerned, it may as well be a mile thick. Many products on the market are considered "scientifically unlikely to make significant improvements" because they don't penetrate the epidermis; they simply create a nutrient rich barrier between the environment and the skin.

Nanotechnology has enabled cosmetic producers to formulate ingredients with particles that are 100,000 times smaller than the width of a human hair. Nanotechnology makes it possible to control the molecules and therefore active ingredients are small enough to penetrate the skin. These invasive technologies can tear at the skin or can be injected under the skin. The surface of the skin has dead skin cells but also a lipid (fat) layer that contains very, very small gaps. These gaps are so small that nothing could get between them, but that is of course, until nanotechnology came along. Nanotechnology allows scientists to develop skin care products that deliver active ingredients right to the heart of the skin.

Also these minute nanoparticles do not lump together but disperse uniformly in a flat layer, enabling light to pass through them. This technology has already

led to the development of sunscreens which use nanoparticles of zinc oxide manufactured as a completely clear liquid instead of the familiar thick white paste. Some other products, for example specific moisturizers with certain actives, may use nanosomes (little pocket-like nanoparticles which disintegrate or melt upon application to skin) to expedite the moisturizing effect.

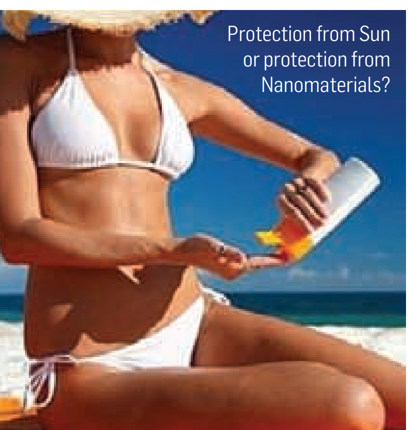
So what is the flipside?

It stands to reason that any substance which can penetrate skin may also make its way into the blood stream and increase risk of disease and reactions. Groups such as Friends of the Earth have expressed concern about their physical properties and their potential risk to cells and organs.

Fiend of Earth published a report entitled "Nanomaterials, Sunscreens and Cosmetics: Small Ingredients, Big Risks" a few years back and since then they have had come down hard on this subject. In the items they reviewed, they found several face creams that list carbon fullerenes as their ingredients- a substance found to cause brain damage in fish and toxic effects in human liver cells.

Manufactured nanomaterials used in sunscreens (such as zinc oxide and titanium oxide) can

1. **Damage human colon cells:** A study from the University of Utah showed that nanoparticles of zinc oxide are toxic to colon cells even in small amounts. In nano scale ZnO particles were around twice as potent as larger ZnO particles in their ability to kill these cells under idealized conditions.
2. **Damage brain stem cells in mice:** A study from China found that zinc oxide nanoparticles can damage the brains of mice by killing important brain stem cells. In another study, Japanese scientists injected pregnant mice with nano titanium dioxide and recorded changes in gene expression in the brains of their fetuses. These changes have been associated with autistic disorders, epilepsy and Alzheimer's disease.
3. **Travel up the food chain from smaller to larger organisms:** A study by researchers at Arizona State University, the Georgia Institute of Technology, and Tsinghua University in China found through a dietary experiment that Daphnia (a "water flea" that provides important nutrition for aquatic life) can transfer nano titanium dioxide to larger organisms (in this case Zebrafish).


Protection from Sun or protection from Nanomaterials?

The current state of the science seems to suggest that as long as nanoparticles in sunscreens stay on top of the skin rather than penetrating it, they are an effective and long lasting barrier against Ultraviolet radiation from the sun. With so many conflicting opinions and views that are out there, it might be some time before we will be able to answer the question if nanotechnology is indeed the key to unlocking the secret to eternal youth.

World War III

The end of the world?

It is the curse of science- no matter what it comes out with, it has the power to both create as well as destroy. Nanotechnology is no exception to this rule. What's particularly worrying is that nanotechnology as a weapon of war has much more scope than any other weapon of war. Within our lifetimes, we might be a witness to battles on a scale never before seen. Powered by molecular manufacturing, near-future wars may threaten our freedom, our way of life, and even our survival.

Recent U.S. planning and policy documents foretell "how wars will be fought in the future," and warn of new or re-emergent "global peer competitors" in the 2010-2025 time frame. If this prediction comes to pass, it is assembler-based nanotechnology that will tip the scales. The perfection of nuclear explosives resulted in a strategic stalemate; as each nation rely to some degree on other nations for trade or security, or both. But a proposed new form of manufacturing that makes use of massively parallel, automated molecular machine systems (molecular manufacturing) has the potential to change all that.

The possible applications of nanotechnology to advanced weaponry are fertile ground for fantasy. Three-dimensional assembly of nanostructures in bulk will yield much better versions of most conventional (nonnuclear) weapons; e.g., guns can be lighter, carry more ammunition, fire self-guided bullets, incorporate multispectral gunsights or even fire themselves when an enemy is detected. Kevlar, the backbone fiber of bulletproof vests, could be replaced


Will it sound the death knell for humanity?

with materials that not only provide better protection but store energy and monitor the health status of our soldiers. Science fiction writers can and do have a lot of fun imagining such things.

Imagine bullets that pack more computer power than the largest supercomputer in existence today, allowing them to perform real time image analysis of their surroundings and communicate with weapons tracking systems to acquire and navigate to targets with greater precision and control. Or imagine UAVs equipped with chemical sensors based on nanotechnology capable of pinpointing a single molecule out of billions and producing incredible photo resolutions

In fact nanotechnology even offers vivid possibilities for creative mass murder. For example, for some reason one of the most frequent flights of fancy is the programmable genocide germ that replicates freely and kills people who have certain DNA patterns. Such a weapon is possible, but it is dangerous to its creators as well. How does one go about overcoming and attacking a nanotechnic foe that doesn't depend on people to run his war machine.

Inhumanly quick

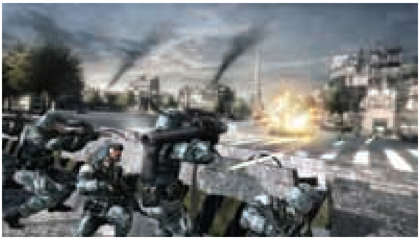
Killing is not difficult; what is difficult is to kill with impunity when one's enemy is well armed and numerous. War is more often a contest to suppress one enemy's capabilities before the enemy can suppress ones. This doesn't leave much room for fancy swordplay or gothic revenge scenarios in serious combat. An actual nanotechnic war, if one ever occurs, is likely to be inhumanly fast and enormously destructive.

The possibility of the development of assembler-based molecular nanotechnology presages a potential for disruption and chaos in the world system and is a cause of concern. What is listed below might turn out to be the events which might lead to a third and the last World War.

1. The prospect of revolutionary advances in military capabilities will stimulate competition to develop and apply the new technologies toward war preparations. No country will be able to afford to fall behind, as that would imply an intolerable security risk.
2. A race to develop early military applications of molecular manufacturing might yield sudden breakthroughs, leading to the emergence of new and unfamiliar threats, and provoking political and military reactions which further reinforce a cycle of competition and confrontation.

3. With molecular manufacturing, international trade in both raw materials and finished goods will get replaced by decentralized production for local consumption, using locally available materials. The absence of international trade will lead to the death of common interest
4. With almost two hundred sovereign nations, each struggling to create a new economic and social order, perhaps the most predictable outcome is chaos: shifting alignments, displaced populations, power struggles, and conflicts inflamed by demagogues, etc.
5. If nuclear weapons remain limited in number, advanced nanotechnology could facilitate extensive civil defense construction, and provide active defense and counterforce weapons, undermining the nuclear "balance of terror" and creating the appearance of a possibility of victory in a war between major powers.
6. Advanced nanotechnology should also facilitate a possible nuclear rearmament to levels manifold higher than those of any other War the world has seen. Thus it is possible that the result of a nanotechnic arms race will be rampant nuclear proliferation and the expansion of major nuclear arsenals to warhead counts in the hundred thousands or millions
7. In the event of a showdown, an imbalance in deployed hardware could allow one side to strike the weaker one with impunity and ensure victory. If military production is based on a self-replicating capital base with a short generation time, unprecedentedly large masses of military hardware could be produced in an unprecedentedly short time.
8. Even if two sides are evenly matched, high levels of deployed armaments may be militarily unstable, in that a surprise attack could perhaps decimate the opposing force before it could even respond.

The nanotechnic era will be fundamentally different from the era in which nuclear weapons were developed and came to dominate the possibilities for global violence. We have managed to avoid a nuclear war only because the bombed-out cities of the Second World War, and the nuclear holocausts of our imagination, have persuaded rational minds that there can be no expectation of a meaningful victory in total war between states armed with hundreds of deliverable nuclear weapons.



Can we fight it?

But nanotechnology will carry this evolution to the next step: deterrence will become obsolete, as it will not be possible to maintain a stable armed peace between nanotechnically-armed rivals. Thus, a runaway nanotechnic arms race may be a race to nowhere; there may be no further island of stable military balance out there, even if we could manage to avoid war along the way.

War against Terrorism

On March 31 2011, at the 241st National Meeting & Exposition of the American Chemical Society (ACS) in Anaheim, California, Allen Apblett presented a new ink-like explosive detector/neutralizer that can be used anywhere against terrorist explosives including battlefields, airports, and subways. This spray-on material both detects and renders harmless the genre of terrorist explosives responsible for government restrictions on liquids that can be carried onboard airliners.

The material is a type of ink made of tiny metallic oxide nanoparticles. The ink changes color, from dark blue to pale yellow or clear, in the presence of explosives. It also changes from a metallic conductor to a non-conducting material, making electronic sensing possible.

This color-change feature allows the material to work as a sensor for quickly detecting the presence of vapors produced by explosives. Soldiers or firefighters could wear the sensors as badges on their uniforms or use them as paper-based test strips. Airports, subways and other facilities could use the sensors as part of stationary monitoring devices.

The same color-changing material can also serve as an explosives neutralizer. Firefighters and bomb squad technicians could spray the ink onto bombs or suspicious packages until the color change indicates that the devices are no longer a threat. Technicians could also dump the explosives into vats containing the ink to neutralize them.

Peroxide-based explosives, made from hydrogen peroxide, are the most easily made explosive and until now have been very hard to detect. Triacetone triperoxide, or TATP, is another substance which is sometimes used in suicide vests and improvised explosive devices and is not the easiest thing to detect. This new ink provides a quick way to detect and test these explosives, which might be hidden in clothing, food, and beverages. The ink contains nanoparticles of a compound of molybdenum, a metal used in a wide variety of applications including missile and aircraft parts. The dark blue ink reacts with the peroxide explosives and turns yellow or clear. When used as an electronic sensor, the highly-sensitive material is capable of detecting TATP vapors at levels as low as a 50 parts per million, equivalent to a few drops of the vapor in a small room,

within 30 seconds. The same chemical reaction allows the materials to serve as an explosives neutralizer.

This methodology can cause the paradigm shift that finally wins the war against terrorism. Until now, car bombs and other types of explosive weapon have been the primary effective weapons of terror, providing terrorists with their publicity and their public image. This new breakthrough in nanotechnology could see the end of the bombs and the bloodshed.

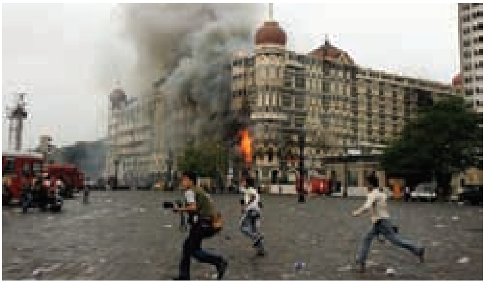
About a month ago, Australian scientists at the University of Technology in Sydney developed a new method of recovering usable fingerprints from old evidence, using nanotechnology. This new method detects dry and weak fingerprints that are not revealed by traditional techniques. It reveals much sharper detail of amino acid traces from old fingerprints than existing methods

According to one of the researchers Xanthe Spindler, what sets their research apart from others is that they are employing nanotechnology to give degraded samples sharper detail. It has the potential to help police reopen unsolved cases and at the same time, get better fingerprints.

So what does it mean?

What the reports and news are pointing at is that there's a new warrior in the fight against terrorism, and it's not a well-trained soldier or a missile, but the tiny nanomaterials. Nanoparticles hold the potential to become our biggest arsenal against biological warfare weapons such as germs, bacteria and spores like anthrax.

With the broad reach nanotechnology has in terms of capabilities, the direct applications for the protection against terrorism, is only limited by our imagination and how rapidly the technology advances. Nanotechnology will advance sensors and protective equipment and current research and development efforts are working on micro power generating devices, which could find application in microscopic self-powered reconnaissance and surveillance devices like listening devices, vibrations sensors as well as supplying power to sensor networks


Fight against terror

Hybrid Nanomaterials will produce orders of magnitude improvements in high-

selectivity and high-sensitivity sensors for biological and chemical detection. This advanced detection of harmful chemical and biological agents; micro sensors for radioactivity, low-power or self-powering consumption security electronics, polymer electronics, nano-optics will provide capabilities that are not available today. Another critical area is the development of nanofabrics. Nanofabrics have unique properties like decreased receptivity to chemical or biological agents, materials with the ability to expand and contract (like a thermostat) as to exhaust or conserve body heat, or to resist the penetration of a bullet.

Imagine, in a few years we will have advanced sensor networks that are self-powered and have the smarts to communicate from sensor to sensor and the ability to detect very small amounts of chemicals or biological agents installed in the water supplies across the country. Once a single sensor node detects the presence of one of the agents, it communicates to the others what hit was found and receives their verification. Once verified, the information is communicated to the control sensor that relays the information back for immediate action. Or imagine using it in underwater sensor networks to detect the movement of ships into and out of our ports and could detect chemical, biological or radiological materials in cargo containers.

One of the early Nanotechnology successes was material that had the characteristics of Gortex (used in bulletproof vests) with the look and feel of regular wool. Super strength nanofabrics sandwiched into normal contraction materials are expected to improve blast resistant construction practices making commercial and governmental structures much more resilient against bomb blasts. Bomb resistant containers for cargo and luggage on ships and aircraft, bomb resistant glass for office buildings and government complexes, advanced structural members that have the strength by are pliable to absorb the energy of a blast are all currently being investigated as real world application of nanotechnology.

Although nanotechnology is based in the research labs today, the advances made to date have illustrated the significant value this technology can bring. The enhanced characteristics of materials will allow us to create new and innovative devices to protect all of us from terrorism, both directly through safer construction designs and indirectly through intelligence and surveillance. With each passing day, the promise of nanotechnology, as our main weapon against terrorism, becomes more and more apparent.

Evolution into Cyborgs

According to Arthur C. Clarke Lifetime Achievement Award winner, futurist and inventor guy Ray Kurzweil, within the next 20-25 years, our mastery of nan-

otechnology will be at such a level that we'll basically be immortal cyborgs. The American - dubbed the smartest futurist on Earth by Microsoft founder Bill Gates - has consistently predicted new technologies many years before they arrived. According to Ray


Evolution into Cyborgs

- In around 20 years, nanotechnology will equip us with the means to reprogramme our bodies' stone-age software so we can halt, then reverse, ageing.
- Nanobots, blood cell-sized submarines, are being tested in animals and they will soon be used to destroy tumors, unblock clots and perform operations without scars. Ultimately, nanobots will replace blood cells and do their work thousands of times more effectively.
- Within 25 years we will be able to do an Olympic sprint for 15 minutes without taking a breath, or go scuba-diving for four hours without oxygen.
- Heart-attack victims - who haven't taken advantage of widely available bionic hearts - will calmly drive to the doctors for a minor operation as their blood bots keep them alive.
- If we want to go into virtual-reality mode, nanobots will shut down brain signals and take us wherever we want to go. Virtual sex will become commonplace. And in our daily lives, hologram-like figures will pop up in our brain to explain what is happening.

These technologies should not seem at all fanciful. Mobile phones are a perfect example. Our phones now perform tasks we wouldn't have dreamed possible 20 years ago. Today our mobile phone is a million times less expensive and a thousand times more powerful, than a computer 20 years back. That translates to a capability that's a billion times more but for the same price. In a similar manner we will experience another billion-fold increase in technological capability for the same cost in the next 25 years.

So we can look forward to a world where humans become cyborgs, with artificial limbs and organs.

Cyborg Soldiers

Cyborg soldiers are a logical evolutionary link between humans and robots. Yesterday's soldier went into combat alone. Today's soldier is enhanced by human controlled robots. Tomorrow's soldier will be a soldier cyborg, a cybernetic

organism enhanced by everything technology has to offer.

In the U.S. Future Force combat systems are being tested and designed to make the 21st century American cyborg soldier a more effective instrument of war, a veritable cyborg able to communicate with augmented cognition more speedily and efficiently. The U.S. military is funding projects to integrate human with artificial intelligence.


Cyborg Soldiers

- **Problem:** Human brains are superior to computers at visual recognition but inferior at information processing.
- **Solution:** Human-machine integration.
- **Human component:** A soldier or analyst who scans scenes or images.
- **Machine component:** Sensors that monitor the brain's activity and relay information about it to commanders or computers.


Combining Man and Machine

The 'Brain Interface Program' is one of the most lavishly funded of nearly all the DARPA bioengineering efforts (the project has been given over $24 million budget). It is aimed at developing ways to 'integrate' soldiers into machines -literally- by wiring them (remotely or directly) to their planes, tanks, or computers. An implantable brain chip has been implemented as well via the integration of stimulus-response signals in the brain via electrodes. In fact it if often said that the human is becoming the weakest link in defense systems.

Combining man and machine to enhance innate soldier capabilities is the hallmark of a soldier-cyborg transformation. Increasing the man-machine interface in the unpredictable environment of war has enormous potential to change the human dimension of war. The immediate future promises to hold some very interesting prospects for cyborg soldiers.

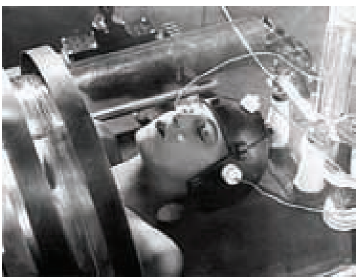
Cybernetics

Human Cybernetics in the field of life extension, refers to how technology has, is and will evolve to support the ideology of extending human lifespan. Scientists already possess prosperous knowledge in how to avoid some degenerative dis-

ease through supplements and nutrition consumptions. These are some medical progresses, which will enrich the biotechnology revolution and transcend a fruitful birth to nanotechnology. It might turn out that the future of cybernetics transcends human kind into a biologically immortal Cyborg

We are aware of common technology. However, medical advancement seldom hit the headlines for many weeks; they are often given little attention. They are veiled behind contemporary technology and cheapskate news on latest gadgets, violence, and private life of pop-stars. However, intelligent machines are already spurring to the surface. There are a number of projects focusing on creating biological microelecromechanical systems (bioMEMS). Their intent is from diagnostic to offer therapeutical treatment to pathologies identified through our blood stream. What's more, it is far from science fiction.

The University of Illinois at Chicago created a 'capsule' of seven nanos, some years ago. This 'nano-capsule' was used in experiments to protect organs and cells such as the pancreatic islet cells from antibodies. This method has proven to cure diabetes type I for rats. This could perfectly work for humans.



Cybernetics

Cybernetics in fact goes beyond finding cures to even replacing organs. For instance, our heart is a performing machine yet with a myriad of failures. These failing weaknesses are tarnishing longevity. The heart is an organ that can prematurely cause death through heart disease and heart attacks. Nowadays, artificial hearts are available and slowly advancing. Artificial hearts are far from being perfect, but will gradually improve, and thus when signs of premature weaknesses are spotted in the heart it can be replaced.

The trend is towards total re-design, where the bloodstream itself genetically modified to integrate the molecular nanobots. The most complex organ to deal with is the brain. Our actual advanced state of technology is unable to identify where memory is precisely located and how it is processed. We only know that the brain has a mind, and this mind might be the whole brain or only a part of the brain. However we are not far from unraveling the mysteries of the brain

This is an advance state of metamorphosis for human to become 'Cyborgs'. Just like the distanced computer system has moved from the table to our pockets (PDA's) and now they are entering our body, our evolution to cyborgs amy wit-

ness a similar transition Our natural biological condition might in the future be constituted of non-biological and technical components. The radical cybernetic evolution that is taking-off may substantially reengineer our body and extend our lifespan to a biologically immortal state. The prognosis of such changes will in the near future. It might just be like the typewriter phenomenon; replaced by new technology and human through cybernetics transcends to biologically immortal cyborgs.

Death of Humanity and Freedom

Nanotechnology is often referred to as the Fourth Horseman of Transhumanism, with Synthetic Biology, Artificial Intelligence and Virtual Reality, making up the other three. There are many directions, we can go with these four horsemen, but there is a great danger of Nanotechnology being hijacked and its development and application being restricted to the Military and Pharmaceutical Companies. Nanotechnology can be misused to take away our freedom of choice in just about everything, from the food we eat to the medical treatment we want.

Nanotechnology can take away our humanity. Inexpensive, invisible, powerful devices threaten freedom and privacy if they fall into the wrong hands. A totalitarian regime could use nanodevices to coerce its citizens. In the short term, it could monitor them pervasively with tiny sensors or threaten them with nanoweapons. It the long-term, modifying the populace with nanosurgery or even using nanobots to transform the genes of future citizens is not inconceivable. With nanodevices to do the work, large sectors of the population could be selectively destroyed, and intervention by other nations could be discouraged by threats based on expertise in nanotechnology.

A unifying theme in this undercurrent of anxiety toward technology is the belief that certain aspects of the human condition are fixed, inherent, or "natural". According to this perspective, trying to change the constants that have shaped human experience, trying to go beyond the boundaries said to be drawn by nature, is to commit an immoral act. The act is immoral because it changes the conditions that made us human and thus risks bringing our humanity to an end. For example, human beings have never before had the power to change the genetic basis of their thoughts and abilities. This limitation has been an inherent part of what it means to be human.

If the visions of the nanotechnologists come to pass, the impact on society would likely be even more profound than the changes wrought by previous advances in technology. Strange and alien notions like biotech agriculture, in vitro fertilization, cloning, hand-held computers, and the Internet would pale

next to machine life forms, nano-enhanced superhumans, virtual immortality, overwhelming material abundance, and interplanetary colonization. A world where these capabilities were real might, over time, become unrecognizable to people alive today lacking in all the familiar landmarks of everyday experience and common sense. The normal rules of social interaction wouldn't apply when humans share the solar system with non-human life forms of unspeakable power. Customs revolving around the normal cycles of birth, growth, maturity, and death would be obsolete when intelligent beings live for hundreds or thousands of years or longer. The traditional human process of working for a living would become irrelevant if material goods materialized on demand out of vast, living swarms of nanomachines. Arts, skills, and crafts would be rendered meaningless.

If nanotechnology manages to unleash technological changes incomparably more immense than any seen before, the word "human" might become an empty, obsolete expression. If history is any indication, we can't discount the possibility of violent convulsions as old institutions and values collapse. The end of feudalism, the birth of Protestantism, and the expansion of industrial capitalism all witnessed violent resistance from the defenders of an old order being swept away. The building of the first nanorobot, if it occurs, will usher in the same kind of transition period, during which the meaning and future of nanotechnology will hang in the balance. Even in its infancy, in fact, the field has already sparked opposition, with left wing groups calling nanotechnology a symbol of scientific arrogance and the harbinger of a techno-dystopia.

A more subtle threat is that represented by the cyborg. Taking nanodevices into our bodies, either to extend our powers or to extend our lives, creates an intimate relationship between our machines and us. Whether the result is viewed as symbiotic or parasitic, at some point, the needs, values, and orientation of these new individuals may become drastically different from what is currently defined as human. To some, this is an opportunity to revel in, but there is by no means a consensus as to whether this is good for our species or not. The social consequences could be profound:

- Are unmodified humans obsolete (and possibly expendable)?
- As people become cyborgs, are they still part of our community with all the same rights?
- How would the accumulation of power and wealth by "immortals" be handled?
- Who is responsible for the costs of side effects?
- Philosophically, if all natural parts are replaced by nanodevices, and the resulting individual passes the Turing test, do you still have a human?

- Is it a good thing for the species if all humans are replaced this way, or is it an empty fantasy that ends humanity?

Nanotechnology might very well spell the death of humanity, in the very essence of the meaning that the word humanity holds. The thin line that divided humans from other creatures will most likely get blurred by the evolution of cyborgs and other trans-human creatures. Even if we discount the rigidity that the word humanity imposes, and consider it in a holistic all encompassing manner, nanotechnology still has the power to take away our freedom. Nanotechnology can be misused and exploited in order to render humans as mere slaves to the whims and fancies of those nano-enhanced creatures. As we said earlier the plausible future scenarios that might emerge from nanotechnology, are only limited by what our imaginations can conjure. We can only wait and see what the future really holds for us as humans.

Conclusion:

The future of nanotechnology rests in the hands of the current scientists who are ready and able to help guide this very young science into the next realm. There are those who fear the future of nanoscience and there are those who are ready to embrace it. Walking a careful line in cohesive junction with human interests is going to be a tricky but worthwhile accomplishment.

There is a possibility that the future of nanotechnology could also be the end of the science. There is a great burden on the scientists of nanotechnology. These men and women have to be able to keep the progress in play while keeping the interest in nanotechnology alive despite the potential limitations.

Nanotechnology is already quietly expected within the scientific community to be the answer to the world's problems. Just like the previous answer to the world's problems the human element cannot be factored in until the future becomes the present.

Much of the funding for nano—research may very well require something amazing in order to continue. The funding that keeps nanotechnology alive is invested in the potential future progress that this technology promises. If it fails to deliver at least some of the potential, funding and interest might vanish right before the eyes of the scientists who spend their lives trying to increase life's wonders through the manipulation of atoms and molecules.

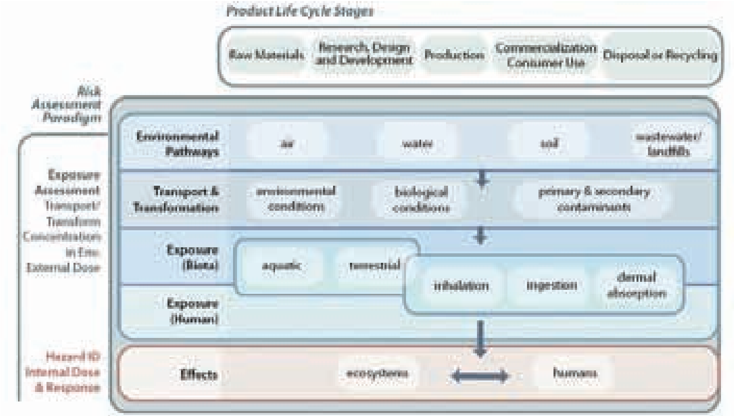
USEFUL INFO

This section explores what the critics are saying about the consequences of the use of Nanotechnology and the ethical issues that confront the developers and financers of this incredible technology. We'll take a glimpse at the countries leading the world in Nanotechnology and provide you links to sites and white papers which will help you dig deeper into this fascinating world

t is imperative that an unbiased and accurate risk assessment, be carried out for any emerging technology, in order to get a holistic picture of its potential benefits and hazards. With the advent of new technologies, including nanotechnology, one should consider the potential unintended consequences to human health and the environment that might accompany development and use of the technology.

The National Nanotechnology Initiative (NNI) came out with the “Nanotechnology Environmental, Health, and Safety (EHS) Research Strategy” in 2011. The research integrated several important concepts – risk assessment and product life cycle stages – into the basic and applied research to understand the EHS impacts of nanomaterials.

Exposure to nanomaterials may occur unintentionally in the environment or through use of nanotechnology-enabled products. The figure above integrates the key risk assessment components – exposure assessment, hazard identification, and dose response (left-hand column) – with nanomaterial life cycle stages – from raw materials through commercialisation and end of product life (across the top) – and the exposure-effects pathways. The concentration of nanomaterials in the environment will depend on factors such as the nature and amount of the nanomaterial released, its physical and chemical properties, and time. The nanomaterials released into the environment may undergo transformation by various environmental conditions such as temperature and salinity, biological conditions such as habitat,



The risk assessment paradigm integrated with nanomaterial life cycle stages.

and the presence of co-contaminants. The transformed nanomaterials, in turn, may modify atmospheric, soil, or water chemistry. These transformations may alter the form of the nanomaterials to which humans and ecosystems are exposed and which are transported through the environment. Biological or environmental systems may be exposed to these dispersed nanomaterials and in ways that could perturb human health or adversely impact the environment.

Health

As nanotechnology is an emerging field, there is great debate regarding to what extent nanotechnology will benefit or pose risks for human health. Although nanoparticles owe all its distinguishing properties to its small size, this very nature makes them a likely suspect for entering the human body unintentionally. The behavior of nanoparticles is a function of their size, shape and surface reactivity with the surrounding tissue. Nano-toxicology can occur in multiple ways:

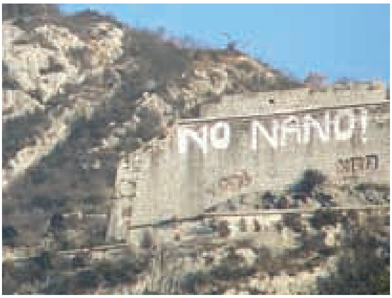
- They could cause overload on phagocytes, cells that ingest and destroy foreign matter, thereby triggering stress reactions that lead to inflammation and weaken the body's defense against other pathogens.
- The large surface of nanoparticles, on exposure to tissue and fluids, will immediately adsorb onto their surface some of the macromolecules they encounter. This may, for instance, affect the regulatory mechanisms of enzymes and other proteins.

The large number of variables influencing toxicity means that it is dif-

ficult to generalise about health risks associated with exposure to nanomaterials – each new nanomaterial must be assessed individually and all material properties must be taken into account.

Environment

As nanotechnology is an emerging field, there is great debate regarding to what extent industrial and commercial use of nanomaterials will affect organisms and ecosystems. Nanopollution caused by the waste generated by nanodevices or during their manufacturing process, might easily penetrate animal and plant cells causing unknown effects.



NO NANO! Grafitti on the Bastille fortress in Grenoble, France

Living organisms do not have a mechanism to deal with artificially engineered nanowaste. They do not appear in nature, and so no evolutionary changes have adapted our immune system to this new threat. This makes nanopollution all the more dangerous.

Society

The "societal implications of nanotechnology" is a term used to include all the potential benefits and challenges that the introduction of novel nanotechnological devices and materials may hold for society and human interaction.

A technology with the potential to revolutionise manufacturing, health care, energy supply, communications and probably defense, will also transform labour and the workplace, the medical system, the transportation and power infrastructures and the military. None of these will be changed without significant social disruption. In fact, many of the most enthusiastic proponents of nanotechnology, see this nascent science (Nanoscience) as a mechanism to changing human nature itself – going beyond curing disease and enhancing human characteristics.

Ethics

As lifesaving tools, nanotechnology is unsurpassed in its promise of an absolute revolution for medical treatment of previously incurable or untreatable conditions. Conversely, when this technology is used to manufacture miniature weapons or explosives the infinite possibilities of far-reaching reverberations is a very

plausible prospect. When trying to incorporate nanotechnological advances into society, there are an array of items that require intensive study, be it the equity of disbursement, privacy rights of individuals and/or corporations, security considerations, the effect on the environment and the social and ethical impact on the human race.

Some interesting ethical questions are raised:

1. If nanotechnology can help us produce goods from inexpensive raw materials, shouldn't it be made available to all?
2. Should poor countries get the technology first? Before we start demanding self-replicating iPhones and laptop batteries that last a month on a single charge?
3. How will molecular manufacturing impact the global economy? Billions of people could lose jobs if the manufacturing process is perfected and made cheap.
4. What if we could live forever? Should we allow people to still have children? If we did, would we not become overpopulated quickly?
5. With nanotechnology, all of us would have to say goodbye to our privacy. Imagine floating nano-cams that fit and see through your clothes hiding in your bedroom or bathroom! Of course you could buy anti-spy nanobots to police your home, but that's just heading back to these days of cat and mouse being played with technology – the hackers vs. the security companies, all over again.
5. Finally, what about human enhancement? Will we cease to be human with all the nano-enhancements we'll do?

Research and news

Nanoparticles are now being widely used in cosmetics, electronics, optical devices, medicine, and in food packaging materials. However, research studies on the dangers and implications of nanomaterials continue to make headlines across the world, at alarmingly increasing frequency. Nanoparticles may well be the asbestos of the twenty first century: a considerable threat to the society.

As we already know by now, materials change their properties considerably on the nano scale and these changes can be exploited for our benefits. However not all changes are for the good. For instance, iron, at the nano level, switches its polarity using energy gained from room temperature heat, thus they are not useful for data storage, as had been hoped. Some nanoparticles crystalline structure changes when they get wet. So, numerous questions

have been raised about their safety and suitability, especially for products destined for human contact.

Researchers generated excitement in 2006, when the destructive nature of certain nanoparticles was found to destroy the cell membranes of cancer cells. In the culture used in the early experiments, healthy cells were affected, but less so than cancer cells. The researchers, in their excitement, suggested that these nanoparticles be used to enclose chemotherapy agents, thus target the cancer cells more directly. The early study, however, only surveyed the nanoparticles in isolation, without the toxic chemicals enclosed in them. However a recent study, presented in the nano journal `Small`, showed that cell cultures (colonies of a particular type of cell growing in a dish) are unaltered when exposed to fullerenes. The same cells do not react when exposed to Gallic acid, an astringent component of tannins found in almost all plants. When present in the cell culture at the same time, however, fullerenes and gallic acid interact to form structures which bind to the cell's surface causing cell death. Hence, it stands to reason that when nanoparticles interact with other particles, unforeseen events might follow. Combining these particles which do not behave as we expect with the already dismal failure of chemotherapy seems like a recipe for disaster.

Regulation

Because of the ongoing argument on the implications of nanotechnology, there is significant debate concerning whether nanotechnology or nanotechnology-based products merit special government regulation.

The nanotechnology label is used on an increasing number of commercially available products – from socks and trousers to tennis racquets and cleaning cloths. The emergence of such nanotechnologies, and their accompanying industries, has triggered calls for increased regulatory arrangements. However, these calls have presently not led to any comprehensive regulation in order to oversee research and the commercial application of nanotechnologies, or any comprehensive labeling for products that contain nanoparticles or are derived from nano-processes.

Although some non-nanotechnology specific regulatory agencies currently cover some products and processes (to varying degrees) – by "bolting on" nanotechnology to existing regulations – there are clear gaps in these regimes. This enables some nanotechnology applications to figuratively "slip through the cracks" without being covered by any regulations.

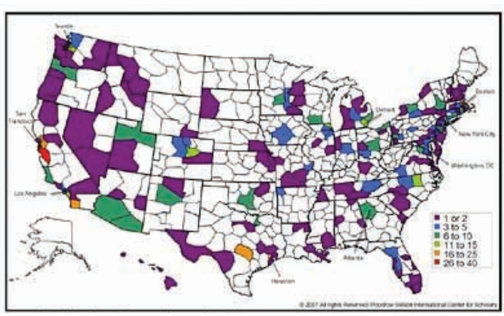
Countries

United States of America

The United States is a hotbed of nanotechnology activity. The US government has joined forces with industry and academia to build expensive facilities and labs around the country. The National Nanotechnology Initiative (NNI) is a US government program to coordinate nanotechnology efforts in the various agencies. The National Science Board, an advisory body of the National Science Foundation (NSF), also funds the NNIN – the National Nanotechnology Infrastructure Network- a joint venture combining the resources of 13 university programs. These schools support research and education in nano-scale science, engineering, and technology and aim to eventually make up an integrated, nationwide system of user facilities.

There are at least 11 US government agencies or departments with research-and-development budgets for nanotechnology. On one hand you have NASA, which is working on using nanomaterials to reduce the weight of spacecraft, while on the other hand the Environmental Protection Agency is funding studies into the use of nanomaterials to clean up pollution – as well as studies to evaluate the potential hazards of nanomaterials themselves. There is money out there in US for people looking for a grant for their next nano-product. The federal research money comes in the form of grants given by individual government departments and agencies in line with their individual missions. It doesn't just stop at financial grants; there are special programs just to seed commercial activities in nano to stimulate economic growth. These programs push small-business collaboration with universities and other research groups.

Even individual states in US are devoting resources to bring its citizens a step closer to the future that nanotechnology promises. One of the big players is the state of New York which has committed over $1.4 billion to establish five Centers of Excellence in nanoelectronics, photonics, bioinformatics, information technology,



Region-wise Nanotech centers distribution.

and environmental systems.As an overseer there is also the Nanotechnology Institute, which is a multistate initiative involving academic and research institutions, corporate partners, private investors, as well as government types interested in supporting economic development. The states participating include New Jersey, Pennsylvania, Maryland, and Delaware – including some international alliances with Japan, Italy, and the United Kingdom thrown in for good measure.

Europe

Europe, now-a-day, sees itself as one large community, in all fields including currency, sports, or technology. As a result, there are a few key Euro-wide organizations driving nanotechnology efforts. The European Union met in March 2000 and charged the European Commission with creating a market for science and technology within a disciplinary division called the European Research Area (ERA) with a budget of 1.3 billion euros. Within the ERA there are a number of technology platforms that are devoted to Nanotechnology like "The Nanobiotechnologies for Medical Applications" and "The European Nanoelectronics Initiative Advisory Council." The European Union has also sponsored the Thematic Network to provide a one-stop source of information for all areas of nanotechnology to business, scientific researchers, and communities. The bottomline remains that Europe is still feeling its way in the nano-realm, defining goals, potential programs, and synergies. But their combined energy will make them bigger players in the years to come.

Japan

In Japan, the nanotech research is overseen by The Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Economy, Trade, and Industry. Japan wants to promote basic research and development in areas that meet society's needs – the life sciences, for example – as well as information and communications technology, and environmental sciences. Japanese efforts in the nanoelectronic devices area will undoubtedly be controlled by technology giants such as NEC, Hitachi, Fujitsu, and Toshiba, whereas pharmaceutical companies will steer development on the biotechnology side. The Council for Scientific and Technological Policy and The Institute of Physical and Chemical Research are some of the key players in Nanotechnology research, along with Tokyo University, the Tokyo Institute of Technology, Osaka University, and Kyoto University

China

The Chinese government funds the National Center for Nano Science and Technology and the National Engineering Research Center for Nanotechnology, for carrying on R&D activities in nanotechnology. Other nanotechnology centers in China include the CAS Nanotechnology Research Center, Nanomaterials and Development Application Center, and the Surface Science, Nanotechnology and Engineering Center.

India

In 2001, India launched their National Nanoscience and Technology Initiative and its activities are divided into three areas:

- Research including synthesis and assembly, characterization of properties, and applications.
- Education, supporting advanced schools, symposia, and training workshops for researchers and scholars.
- Industry, emphasising interaction with industries in a variety of areas, such as nanoelectronics, manopower/particle production, and surface coatings.

The emergence of nanotechnology in India has witnessed the engagement of a diverse set of players, each with their own agenda and role. Nanotechnology in India is a government led initiative and nanotechnology R&D barring a few exceptions is largely being ensued at public funded universities as well as research institutes.

Department of Science and Technology (DST), the chief agency engaged in the development of nanotechnology, initiated India's principal programme, the Nanoscience and Technology Mission (NSTM) in 2007, with an allocation of Rupees 1000 crores for a period of five years. Apart from DSIT, the other key players include:

- DBT (Department of Biotechnology) which supports research in nanotechnology and the lifesciences.
- CSIR (Council of Scientific and Industrial Research) which is a network of 38 laboratories has commissioned R&D in nanotechnology in diverse areas.
- SERC (Science and Engineering Research Council) has also aided projects on nanotechnology.

Several bilateral collaborations have emerged in nanoscience and technology, as it was a part of nearly all the Science & Technology (S&T) agreements between India and other countries. Initiatives for joint R&D have figured prominently with Indian institutes engaging in projects of similar kind in the US, EU, Japan, Taiwan and Russia. The S&T departments of Brazil, South Africa and India

Nanotech India 2011

have embarked on a tri-lateral initiative to developed collaborative programmes in several common areas of interest, and nanotechnology being one of them. The International Science and Technology Directorate (ISAD) of the CSIR that aims to strengthen cooperation between CSIR and international institutions has facilitated workshops and collaborative projects with international partners like South Africa, France, South Korea, China, Japan in the area of nanoscience and technology. Another forum for international collaboration is the Euro-India Net set up under the FP6 between EU and India to encourage collaborations between scientists from the two regions in the area of nanotechnology. A memorandum of understanding also has been signed between India and UNESCO to establish a Regional Centre for Education and Training in Biotechnology, where one of the focus areas is on nano biotechnology.

New kid on the block - Israel

The Israeli government set up the Israeli National Nanotechnology Initiative, with a mission to make nanotechnology the next big thing in industry by leading the way with a variety of initiatives. The INNI has launched partnerships among government, academia, and industry that will allow Israel to step up to the plate in the broader world of nanotechnology. The Israel Nanotechnology Trust is the part of the INNI that raises and distributes money. The Consortium for Nano Functional Materials (NFM) consists of participants from 14 industries and 12 academic research groups which are performing basic R&D in the field of nanomaterials and technologies.

According to INNI estimates, Israel needs to invest at least $300 million in research and development and to get hold on this kind of funding, the INT is looking at a variety of sources, including Jewish organizations. Traditionally, money from Jewish groups went towards supporting immigration to Israel, helping to develop agriculture, and building up military strength. The message that is being presented to Jewish donors is that an emphasis on funding science and

technology – especially nanotechnology – is the way to jumpstart Israel's future.

A country like Israel cannot hope to compete with US or EU in the nanotechnology arena. Still, they may have a shot at becoming leaders in applications of nanotechnology that focus on solving their particular problems, such as water and energy shortages. No wonder Israel is applying nanotechnology to areas of clear practical importance to national survival like water desalination, energy, biotechnology, and semiconductors.

Whitepapers

1. Nanotech: Cleantech
http://bit.ly/q9rAe2 | Cientifica Ltd | March 2007
2. Nanotechnology White Paper
http://1.usa.gov/9u8G87 | US EPA | February 2007
3. The 2011 Report on Global Nanotechnology Funding And Impact.
http://bit.ly/ordMzt | Cientifica Ltd | July 2011
4. Future of Warfare
http://bit.ly/pgq1p5 | Mike Treder, Center for Responsible Nanotechnology | June 2007
5. Nanotechnology: The Next great wave of Innovation
http://bit.ly/nitDEn | NOVA WorkForce Board | September 2003
6. Quantifying the effect of nanotechnologies in CO2 emissions.
http://bit.ly/oUn9Na | Cientifica Ltd. | May 2007

Useful Links

Nanoelectronics

- *http://www.research.ibm.com/nanoscience/index1.html*
- *https://engineering.purdue.edu/Engr/Research/LabsFacilities/INAC/HP*
- *http://www.hpl.hp.com/research/qsr/*
- *http://www.cise.columbia.edu/NSEC/*

Medicine

- *http://ncl.cancer.gov/*
- *http://www.ccne.northwestern.edu/index.htm*
- *http://www.ntc-ccne.org/NTCFamily/Mission.aspx*
- *http://www.ntc-ccne.org/NTCFamily/Mission.aspx*

Military

- *http://web.mit.edu/ISN/research/index.html*

- *http://www.nrl.navy.mil/nanoscience/ext/index.html*

Space

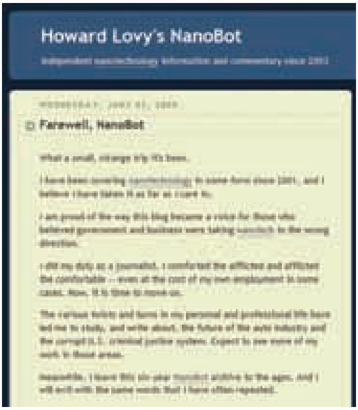
- *http://www.ipt.arc.nasa.gov/index.html*
- *http://mmptdpublic.jsc.nasa.gov/jscnano/*
- *http://snl.mit.edu/mission.html*
- *http://tiims.tamu.edu/*

Research Centers in India

- *http://www.barc.ernet.in/*
- *http://cmet.gov.in/index.html*
- *http://www.csio.nic.in/*
- *http://www.ncbs.res.in/*
- *http://www.ncl-india.org/index.jsp*
- *http://www.nplindia.org/time.php*
- *http://www.rri.res.in/*

Useful sites

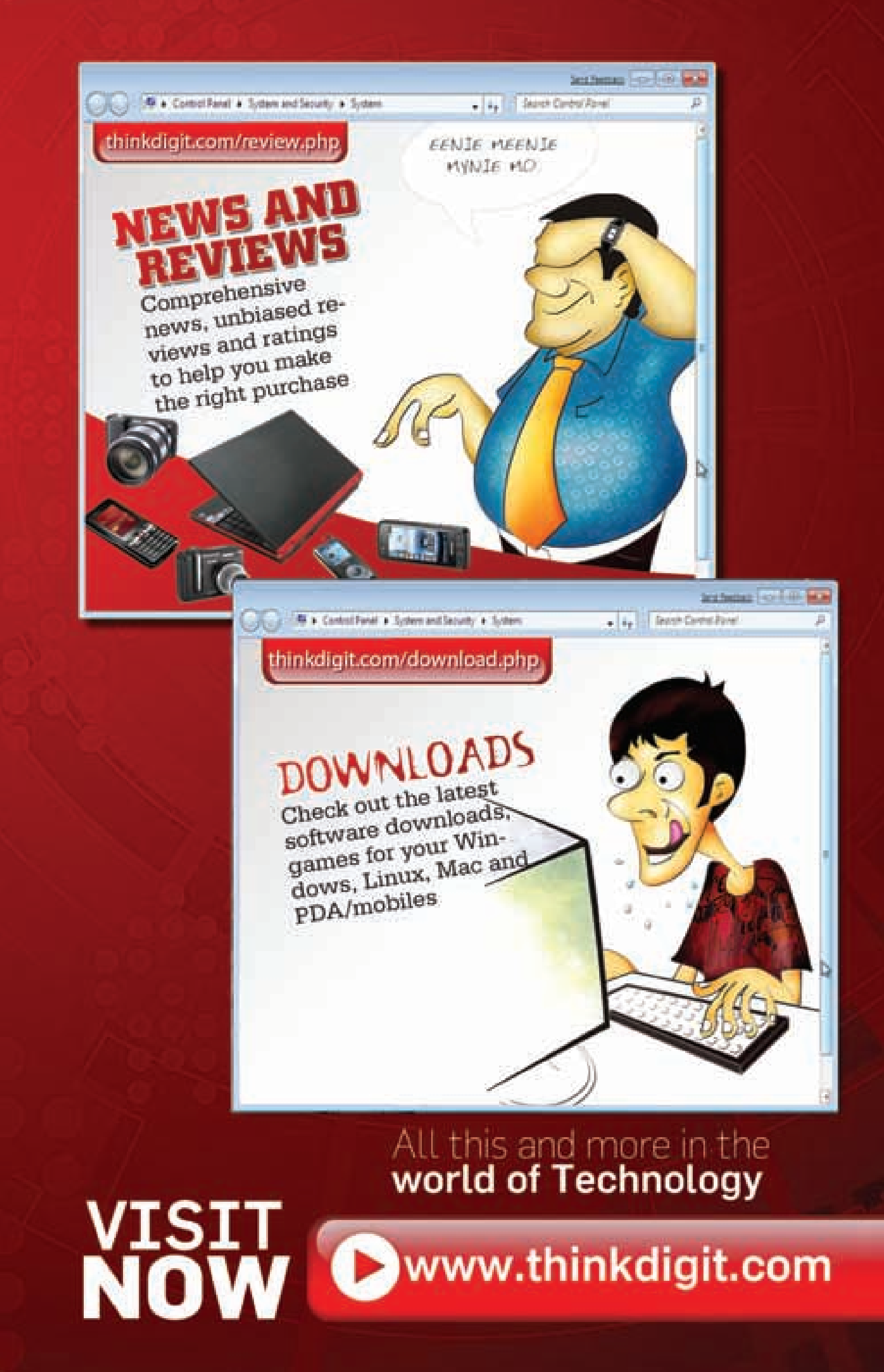
- *www.azonano.com*
- *www.nano.gov*
- *www.nanotechnologyfordummies.com*
- *www.forbesnanotech.com*
- *www.nanobusiness.org*
- *www.phantomsnet.com:*
- *www.fda.gov/nanotechnology*
- *www.nano.org.uk*
- *www.apnf.org*
- *www.foresight.org*
- *www.nsti.org*
- *www.nanotech-now.com*
- *www.howstuffworks.com*



Check out these blogs

Interesting blogs

- *http://nanoparticles.tumblr.com/*
- *http://medicalnanotec.com/*
- *http://nanoscale-materials-and-nanotechnolog.blogspot.com/*
- *http://nanobot.blogspot.com*
- *http://nanotechnologytoday.blogspot.com/*


thinkdigit.com/review.php
EENIE MEENIE MYNIE MO
NEWS AND REVIEWS
Comprehensive news, unbiased re-views and ratings to help you make the right purchase
thinkdigit.com/download.php
DOWNLOADS
Check out the latest software downloads, games for your Win-dows, Linux, Mac and PDA/mobiles
All this and more in the world of Technology
VISIT NOW
www.thinkdigit.com

RNI REGN. No. MAH ENG/2001/3791